

### Dolphinfish (*Coryphaena hippurus*) Rank 9: (Recreational Fishery)

The dolphinfish occurs worldwide in tropical and warm temperate seas in both oceanic and coastal waters (Figure 25, McEachran and Fechhelm 2005). The dolphinfish ranks 9<sup>th</sup> in the recreational fishery with 2.3 million pounds (373,000 fish) landed annually. Only about 4,200 fish are taken in Texas waters.

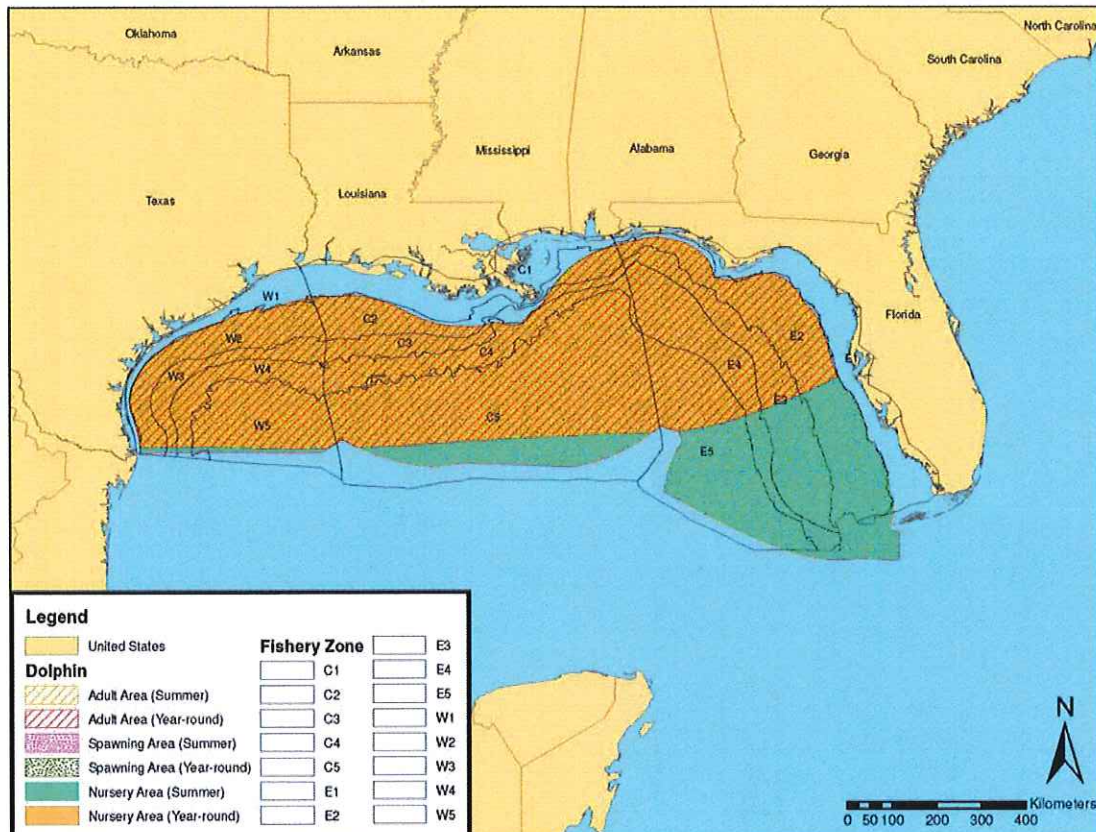


Figure 25. Distribution of dolphinfish in the GOM. Source: NOAA (1985).

In pelagic regions, *Coryphaena hippurus* is commonly found near floating objects apparently because its prey seek refuge under and within the flotsam (Palko, et al. 1982). The dolphinfish is a relatively short-lived fish and are believed to live an average of two years, and a maximum of five years (Beardsley, 1967). Females may spawn two to three times per year and produce between 80,000 and 1,000,000 eggs per event. In waters above 34° C, larvae are found all year, with greater numbers detected in spring and fall. In one study, 70% of the youngest larvae collected in the northern GOM were found at depths greater than 180 meters (Ditty et al. 1994).

A full suite of life-history parameters has not yet been compiled for this species.

**Other Fishes**  
**Rank 10: (Recreational Fishery)**

The generic category “Other Fishes” ranks 10<sup>th</sup> in GOM recreational fisheries in terms of weight. Over 1.9 million pounds are landed annually in the GOM (ex Texas). This represents close to 1.6 million fish. Another 193,000 fish are landed in Texas. No CWIS entrainment assessment can be made for this category.

### **Anchovies (Engraulidae) (Forage Fish)**

Five species of anchovy have been confirmed to occur in the northern GOM and more southerly species may temporarily move north under proper oceanographic conditions (Hoese and Moore 1998, McEachran and Fechhelm 1998). The bay anchovy (*Anchoa mitchilli*) and striped anchovy (*A. hepsetus*) are the most common species in the waters of the northern Gulf (Hoese and Moore 1998). The bay anchovy is restricted to bays, inshore areas, and coastal fresh to brackish waters. The striped anchovy is usually found farther offshore than the bay anchovy. Fertilized eggs and larvae of all anchovy are pelagic. Excluding small fisheries operating off the southern west coast of Florida, there are no commercial or recreational fisheries for any anchovy species in the GOM (NMFS 2008a). No species of sardine are reported in the NMFS Fisheries Statistics Division ST1 and TDPW recreational fishery databases. Nevertheless, anchovies are considered to be an integral component of the forage fish community.

In the GOM, seawater entrainment assessments associated with planned LNG facilities have used the bay anchovy as a proxy species representative of all Engraulid taxa in the Gulf (TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b). Because anchovies are not taken commercially or recreationally, entrainment losses have been evaluated based upon total numbers of age-1 anchovies (all species combined) lost to entrainment relative to the total forage fish population in the GOM (TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b).

### **Life Stages, Daily Instantaneous Mortality, Stage Duration**

$e^2M$  (2005) first derived life-history parameter values based upon references to relevant scientific literature (Appendix Table D9). We know of no information that would improve on those estimates and will use them for CWIS entrainment analyses. The original  $e^2M$  (2005) life-history parameter values for bay anchovy have been used in all of the LNG entrainment analyses in the GOM to date (e.g., TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b).

### **Assessment**

In the GOM, Engraulids spawn throughout the year with peak spawning occurring from March through September (Ditty et al. 1988). Because SEAMAP sampling is conducted primarily during the months of June through November there are no adequate SEAMAP estimates of larval densities for the period December-May. To address this issue, USCG and MARAD (2004), as amended by USCG and MARAD (2005) developed an approach to CWIS Engraulid entrainment based upon monthly abundance data collected by Ditty (1986) offshore Louisiana.

Ditty (1986) reported that the average monthly density of Engraulid larvae in the neritic (continental shelf) waters of the Northern Gulf of Mexico for the period December-May ranged from 1.6 to 193.8 larvae/100m<sup>3</sup> with a period average of 55.3 larvae/100m<sup>3</sup> (Table 26). For the period June-November, average monthly densities ranged from 0.8 to 598.1

larvae/100m<sup>3</sup> with a period average of 141.0 larvae/100m<sup>3</sup>. The ratio of the average larval density from December-May to the average larval density for June through December yielded a comparative ratio of 0.3922. This ratio is used to estimate Engraulids density in the GOM for the period December-May when no SEAMAP sampling occurs: average larval density for December-May equals 0.3922 times the observed average larval density for the period June-November.

Table 27 lists all Engraulid taxa reported in the SEAMAP database. In the vast majority of instances, larvae are identified only to the level of family. For each of the ichthyoplankton tows in the SEAMAP database in which Engraulid taxa were present, all taxa were incorporated into a single density value. For example, for any single tow, if the reported density of Engraulidae was  $x$  larvae/m<sup>3</sup>, and the density of *Anchoa* spp. was  $y$  larvae/m<sup>3</sup>, and the density of *Engraulis eurystole* was  $z$  larvae/m<sup>3</sup> (assume only three taxon reported), then the density of Engraulids for that tow would be  $x + y + z$  larvae/m<sup>3</sup>.

Table 26. Reported average monthly densities (number/100 m<sup>3</sup>) of Engraulids reported by Ditty (1986).

Dec	Jan	Feb	Apr	May		Average
4.0	1.6	2.9	193.8	74.3		55.3
Jun	Jul	Aug	Sep	Oct	Nov	Average
598.1	213.4	3.0	27.6	3.3	0.8	141.0
Ratio of December-May to June-November =						0.3922

Table 27. Engraulid taxa reported in the SEAMAP database.

Taxon	Common Name	Tows
Engraulidae		3387
<i>Anchoa</i> spp.		161
<i>Anchoa hepsetus</i>	Striped anchovy	31
<i>Anchoa mitchilli</i>	Bay anchovy	11
<i>Anchoa lyolepis</i>	Dusky anchovy	4
<i>Engraulis eurystole</i>	Silver anchovy	60
<i>Anchoviella</i> sp. <sup>1</sup>		2
<i>Anchoviella perfasciatus</i>	Flat anchovy	3

<sup>1</sup> Because there is only one species of *Anchoviella*, all *Anchoviella* sp. are actually *A. perfasciatus*.

Table 28 lists the larval densities of Engraulids ( $\pm$  95% CI) as derived from the SEAMAP database for the period June-November and projected daily seawater usage by zone. Daily entrainment is calculated for each zone by multiplying density times daily water usage rate to yield daily entrainment. Daily entrainment rates are multiplied times the exposure period of 182 days (June-November) to yield entrainment. Table 29 lists the larval densities for the period December-May and projected daily seawater usage. Daily entrainment is calculated for each zone by multiplying density times daily water usage rate to yield daily entrainment. Total entrainment is calculated by multiplying daily entrainment rates times



the exposure period of 183 days (December-May) and by the seasonal ratio 0.3922 derived from Ditty (1986). Total entrainment for each season is then summed across all zones to obtain total annual entrainment Table 30.

Table 28. SEAMAP larval densities ( $\pm$  95% CI) for Engraulids for the period June-November and daily seawater usage estimates by zone. Daily entrainment is calculated by multiplying density times daily water usage rate to yield daily entrainment. Daily entrainment rates are multiplied times the exposure period of 182 days (June-November) to yield total entrainment. Shaded area denoted the only zones where future CWIS activity is projected.

Zone	Larval Density (no./m3)			Water Usage (Million m3/day)	Daily Entrainment			Total Entrainment (Millions) Over 182 Days of Exposure		
	Mean	LCL	UCL		Mean	LCL	UCL	Mean	LCL	UCL
E1	2.3676	1.4159	3.3194	0	0	0	0	0	0	0
E2	0.3964	0.2395	0.5533	0	0	0	0	0	0	0
E3	0.1000	0.0581	0.1420	0	0	0	0	0	0	0
E4	0.0484	0.0027	0.0940	0	0	0	0	0	0	0
E5	0.0043	0.0000	0.0099	0	0	0	0	0	0	0
C1	9.8733	7.1066	12.6400	0	0	0	0	0	0	0
C2	3.9281	3.1459	4.7103	0	0	0	0	0	0	0
C3	0.4901	0.3592	0.6211	0	0	0	0	0	0	0
C4	0.3335	0.1639	0.5031	0.05678	18,935	9,304	28,565	3.446	1.693	5.199
C5	0.0468	0.0000	0.0973	0.91986	43,082	0	89,465	7.841	0	16.283
W1	3.9846	2.8131	5.1561	0	0	0	0	0	0	0
W2	6.0124	3.2330	8.7918	0	0	0	0	0	0	0
W3	0.7518	0.5680	0.9356	0	0	0	0	0	0	0
W4	0.1045	0.0666	0.1424	0.01514	1,583	1,008	2,157	0.288	0.184	0.393
W5	0.0542	0.0000	0.1121	0.17791	9,643	0	19,937	1.755	0	3.629

Table 29. SEAMAP larval densities ( $\pm$  95% CI) for Engraulids covering the period December-May and seawater usage estimates by zone. Daily entrainment is calculated by multiplying density times daily water usage rate to yield daily entrainment. Daily entrainment rates are multiplied times the exposure period of 183 days (December-May) and by the seasonal ratio 0.3922 derived from Ditty (1986) to yield total entrainment. Shaded area denoted the only zones where future CWIS activity is projected.

Zone	Larval Density (no./m3)			Water Usage (Million m3/day)	Daily Entrainment (Millions)			Total Entrainment (Millions) Over 183 Days of Exposure		
	Mean	LCL	UCL		Mean	LCL	UCL	Mean	LCL	UCL
E1	2.3676	1.4159	3.3194	0	0	0	0	0	0	0
E2	0.3964	0.2395	0.5533	0	0	0	0	0	0	0
E3	0.1000	0.0581	0.1420	0	0	0	0	0	0	0
E4	0.0484	0.0027	0.0940	0	0	0	0	0	0	0
E5	0.0043	0.0000	0.0099	0	0	0	0	0	0	0
C1	9.8733	7.1066	12.6400	0	0	0	0	0	0	0
C2	3.9281	3.1459	4.7103	0	0	0	0	0	0	0
C3	0.4901	0.3592	0.6211	0	0	0	0	0	0	0
C4	0.3335	0.1639	0.5031	0.05678	18,935	9,304	28,565	1,359	0.668	2,050
C5	0.0468	0.0000	0.0973	0.91986	43,082	0	89,465	3,092	0	6,421
W1	3.9846	2.8131	5.1561	0	0	0	0	0	0	0
W2	6.0124	3.2330	8.7918	0	0	0	0	0	0	0
W3	0.7518	0.5680	0.9356	0	0	0	0	0	0	0
W4	0.1045	0.0666	0.1424	0.01514	1,583	1,008	2,157	0.114	0.072	0.155
W5	0.0642	0.0000	0.1121	0.17791	9,643	0	19,937	0.692	0	1,431

Table 30. Estimated annual entrainment of Engraulid larvae and eggs. Values are derived by multiplying Engraulid larval density times the egg to total larvae ratio.

Component	Total Entrainment Over 365 Days of Exposure		
	Mean	LCL	UCL
Larval Entrainment	18,587,085	2,617,106	35,559,435
Egg/Larval Ratio	0.3315	0.3315	0.3315
Egg Entrainment	6,161,619	867,571	11,787,953

The egg ratio was calculated by dividing total average egg density across Zones C4, C5, W4, and W5 by average total larval density (all taxa) across Zones C4, C5, W4, and W5. The ratio for this case was 0.3315. This ratio was multiplied times total Engraulid entrainment to yield total Engraulid egg entrainment. (see Table 30).

The number of age-1 equivalents was then calculated for the base, high-mortality, and low-mortality life history values as described in Appendix Table D9 using the method and data presentation format described by e<sup>2</sup>M (2005) (Tables 31-33). The number of age-1 equivalents represents the number of anchovy eggs and larvae lost to entrainment that would have otherwise survived natural mortality during the first year of life (i.e., reached the age of 1). The number of age-1 equivalents is then compared to the total forage fish population in the GOM to determine the proportionate loss attributed to CWIS entrainment (TORP 2006; USCG and MARAD 2005a, 2005b, 2006a, 2006b).

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Table 31. Age-1 equivalents for Engraulids using base life-history mortality estimates across all life stages.

Stage	Instantaneous Mortality	Duration (Days)	Natural Mortality per Stage	Fishing Mortality per Stage	Total Mortality per Stage	Fraction Surviving	Correction
Egg	1.044	1	1.0440	0	1.0440	0.3520	0.52076
Larvae	0.2059	34	7.0006	0	7.0006	0.0009	0.00182
Juvenile	0.004	330	1.3035	0	1.3035	0.2716	
	Total =	365		Total =	9.3481		

Stage	Number Potentially Entrained			Fraction Surviving to Age 1	Number Surviving to Age 1+		
	LCL	Mean	UCL		LCL	Mean	UCL
Egg	2,617,106	18,587,085	35,559,435	0.000129	337	2,396	4,583
Larvae	867,571	6,161,619	11,787,953	0.000495	429	3,047	5,830
Juvenile							
	Total =				766	5,443	10,413

Table 32. Age-1 equivalents for Engraulids using low mortality estimates across all life stages.

Stage	Instantaneous Mortality	Duration (Days)	Natural Mortality per Stage	Fishing Mortality per Stage	Total Mortality per Stage	Fraction Surviving	Correction
Egg	0.69	1	0.6900	0	0.6900	0.5016	0.66807
Larvae	0.1804	30.63	5.5257	0	5.5257	0.0040	0.00793
Juvenile	0.004	333.4	1.3336	0	1.3336	0.2635	
	Total =	365		Total =	7.549252		

Stage	Number Potentially Entrained			Fraction Surviving to Age 1+	Number Surviving to Age 1+		
	LCL	Mean	UCL		LCL	Mean	UCL
Egg	2,617,106	18,587,085	35,559,435	0.000701	1,835	13,035	24,937
Larvae	867,571	6,161,619	11,787,953	0.002091	1,814	12,884	24,649
Juvenile							
	Total =				3,649	25,919	49,586

Table 33. Age-1 equivalents for Engraulids using high mortality estimates across all life stages

Stage	Instantaneous Mortality	Duration (Days)	Natural Mortality per Stage	Fishing Mortality per Stage	Total Mortality per Stage	Fraction Surviving	Correction
Egg	1.94	1	1.9400	0	1.9400	0.1437	0.25130
Larvae	0.231	34	7.8540	0	7.8540	0.0004	0.00078
Juvenile	0.01	330	3.3000	0	3.3000	0.0369	
	Total =	365		Total =	13.094		

Stage	Number Potentially Entrained			Fraction Surviving to Age 1+	Number Surviving to Age 1+		
	LCL	Mean	UCL		LCL	Mean	UCL
Egg	2,617,106	18,587,085	35,559,435	0.000004	9	67	128
Larvae	867,571	6,161,619	11,787,953	0.000029	25	176	337
Juvenile							
	Total =				34	243	465

The age-1 tables above were presented to maintain continuity with previous LNG assessments in the GOM (USCG and MARAD 2003, 2004, 2005a, 2005b, 2006a, 2006b; TORP 2006). Conceptually, using high mortality life-history values instills greater natural mortality on eggs and larvae. The number of age-1 equivalents lost to entrainment is less because a higher proportion of those eggs and larvae would have been lost to natural mortality anyway. Conversely, using low mortality life-history values instills lower natural mortality on eggs and larvae. The estimated number of age-1 equivalents lost to entrainment is higher for lower mortality life history data because a lower proportion of those eggs and larvae would have been lost to natural mortality in the first place

We suggest that the use of low- and high-mortality life-history estimates may be misleading and exaggerates projected impacts of CWIS entrainment. In the low mortality case (see Table 32), the two worst-case extremes (lowest natural mortality rate, lowest stage duration) are used multiplicatively. Natural mortality ( $d^{-1}$ ) times stage duration in days yield stage mortality. The lower the stage mortality the higher the proportion of entrained larvae (or eggs) that are considered lost to the environment as a direct impact of the CWIS entrainment. In the cases above, lowering  $M$  from  $0.2059 d^{-1}$  (base case) to  $0.1804 d^{-1}$  (low mortality case) and simultaneously lowering stage duration from 34 to 30.63 days results in a five-fold increase in the projected number of age-1 equivalents lost to entrainment. That the two worst-case life-history estimates would co-occur naturally is highly problematic. Unless there is direct evidence that such a situation can occur within reasonable expectation, the base case model represents the best scenario for judging the effects of CWIS entrainment.

Lastly, the projected losses of age-1 equivalents was compared to the projected standing stock of forage fish in the GOM. The estimated total biomass of small pelagic species (e.g., forage fish) in the GOM is 5,844,454,571 pounds (USCG 2005). Using a

rough estimate of 0.0063273 pounds per forage fish (USCG 2005) yields a population estimate of 923,688,551,357 forage fish in the GOM.

The projected percent loss for the base case, mean entrainment scenario was 5.893 E-7 (Table 34).

Table 34. Projected annual entrainment loss of Engraulids as a percent of GOM forage fish (923,688,551,357).

Case	LCL	Mean	UCL
Base	8.297E-08	5.893E-07	1.127E-06
Low	3.951E-07	2.806E-06	5.368E-06
High	3.708E-09	2.633E-08	5.038E-08



## LITERATURE CITED

This section contains references for all the literature cited in this document. Included are references appearing as tabular entries in Tables 6-9. These tables were largely taken from published reviews with principal authors being cited in the caption. The citations within each table were those provided by the principal author as per the specific publication. Many of these papers were not actually reviewed by LGL in the preparation of this document.

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## **APPENDICES**

Appendix A. Description of Methods for Analyzing SEAMAP Fish Larvae and Egg Data

Appendix B. Description of Methods for Analyzing SEAMAP Fish and Invertebrate Trawl Data

Appendix C. Gulf of Mexico Newbuild Rigs and Fleet Size Changes.

Appendix D. Life-History Summary Tables

## **Appendix A**

### **Description of Methods for Analyzing SEAMAP Fish Larvae and Egg Data**

LGL Ecological Research Associates, Inc.  
1410 Cavitt Street  
Bryan, Texas 77801

Updated: October 29, 2004

### **Data Tables**

Three SEAMAP data tables are used together to analyze fish larvae and egg catch rates:

- **STATCARD.** This data table contains when and where sampling operations take place. Fields relevant to these analyses include (note underscores “\_” in field names have been replaced by periods “.”):
  1. CRUISE.NO
  2. VESSEL
  3. P.STA.NO
  4. S.LATD
  5. S.LATM
  6. S.LOND
  7. S.LONM
  8. S.STA.NO
  9. MO.DAY.YR
  
- **ICHSTRWK.** This data table contains information on the plankton samples taken at each station. It contains all of the egg data. Fields relevant to these analyses are listed below:
  1. CRUISE.NO
  2. VESSEL
  3. P.STA.NO
  4. SAMPLE.NO
  5. GEAR.CODE
  6. MESH.CODE
  7. VOL.FILT
  8. NO.EGGS
  9. EGGS.ALIQUE



- **ICHSTRWK.** This is the individual taxa data table. It contains information on each individual fish larvae taxa collected in each sample. Relevant fields are listed below:

1. CRUISE.NO
2. VESSEL
3. P.STA.NO
4. SAMPLE.NO
5. SAMP.STAT
6. TAXONOMIC
7. BIOCODE
8. MEAS
9. NOT.MEAS
10. ALIQUOT

## **Merging Data Tables**

The STATCARD and ICHSTRWK data tables can be merged based on 3 fields, CRUISE.NO, VESSEL, AND P.STA.NO. To further merge the resulting set with the ICHSAR set, the SAMPLE.NO field must be included in the merge key.

## **Analysis Steps**

The STATCARD data table, with its station time and place information is the core data table for these analyses. The data table is read into a database file (R data.frame), where the station latitude and longitude values are converted to decimal degrees, and the sample date is used to create variables for sampling month and year. Next, the ICHSTRWK data table is read into a database file (R data.frame), and restricted to records with GEAR.CODE equal to 1 and MESH.CODE equal to 3, which represent the .333 m mesh, 60 cm Bongo net. At this time we also convert the value for VOL.FILT from -9 to NA, to adjust for differences in handling of missing data. [The NO>EGGS variable is also adjusted by the size of the EGGS.ALIQU variable, multiplying subsampled aliquots by the appropriate value to set them equal to 1/1 aliquots.]

**Analysis Constraints.** There are no year or month restrictions placed on the station data. Stations were restricted to a somewhat arbitrary rectangle around the proposed site, with the -93.65 and -92.834 degree longitude lines making the vertical sides, and the 29.00 and 29.334 degree latitude lines making the horizontal sides. All stations that were outside of the rectangle were eliminated.

**Data Table Joins.** At this point the station and ichstr data tables were merged using the fields CRUISE.NO, VESSEL, and P.STA.NO as the merge key.

**Egg CPUE.** Number of eggs per cubic meter of water filtered (Egg.cpue) are calculated for each sample in the combined station-ichstr data table where the VOL.FILT variable is greater than zero. The mean Egg.cpue and 2 standard errors are then calculated to produce the mean value with upper and lower confidence intervals.

**Preparing the Fish Larvae Data Table.** The ICHSARWK data table is read into a database file (R data.frame), and is restricted to records containing a SAMP.STAT (sample status) value of either 1 or 2 (the only values valid for quantitative analysis and summaries, David Hanisko, NMFS, pers. comm.). The variables MEAS and NOT.MEAS are adjusted to zero values where value in the record is -9, then they are added together to create the total count variable, which is then adjusted by the ALIQUOT variable factor to represent a whole sample. This database table is then merged with the station-ichstr data table using the four variables, CRUISE.NO, VESSEL, P.STA.NO, and SAMPLE.NO as the merge key.

**Fish Larvae Summary Values.** Total fish larvae catch for each sample is aggregated, and divided by the sample VOL.FILT variable to create the sample catch per cubic meter of water filtered (Fish.cpue). Then the mean Fish.cpue and 2 standard errors are calculated to produce the mean value with upper and lower confidence intervals, both by month of sampling, and for the overall period.

**Fish Larvae Individual Taxa Catch Rates.** Calculating the catch per cubic meter of water filtered for each taxa caught at anytime in the included samples requires construction of a matrix with one record for each taxa for each sampling record (total size of matrix will be number stations X number of taxa). This data table is then merged with the data table created above (station-ichstr-ichsar, which represents taxa actually caught at each sampling station), and all records with missing values are set to a value of zero. The catch rate per cubic meter of water filtered (Taxa.cpue) can now be calculated for each taxa for each station. These data can be summarized to produce the mean cpue for each taxa along with standard errors, so that upper and lower confidence intervals can be provided.

## **Appendix B**

### **Description of Methods for Analyzing SEAMAP Fish and Invertebrate Trawl Data**

LGL Ecological Research Associates, Inc.  
1410 Cavitt Street  
Bryan, Texas 77801

Updated: February 26, 2009

### **Data Tables**

Two SEAMAP data tables are used together to analyze fish and invertebrate catch rates:

- GOMTrawlfix. This data table contains when and where sampling operations take place. Fields relevant to these analyses include (note underscores “\_” in field names have been replaced by periods “.”):

1. STATIONKEY
2. VESSEL
3. CRUISE
4. STATION
5. SEAMAP\_NUM
6. DATA\_SOURCE
7. START\_DATE
8. TIME\_ZONE
9. START\_TIME
10. START\_LAT\_D
11. START\_LAT\_M
12. START\_LONG\_D
13. START\_LONG\_M
14. START\_DEPTH
15. END\_TIME
16. END\_LAT\_D
17. END\_LAT\_M
18. END\_DEPTH
19. GEAR\_CODES
20. SURFACE\_TEMP
21. BOTTOM\_TEMP
22. AIR\_TEMP
23. BAROMETRIC\_PRESSURE
24. WIND\_SPEED
25. WIND\_DIRECTION
26. WAVE\_HEIGHT

27. SEA\_CONDITION  
28. VESSEL\_SPEED  
29. SHRIMP\_STATION  
30. TOW\_NUMBER  
31. NET\_NUMBER  
32. GEAR\_TYPE  
33. GEAR\_SIZE  
34. MESH\_SIZE  
35. MINUTES\_FISHED  
36. WATER\_COLOR  
37. BOTTOM\_TYPE

- GOMCatchnoq. This data table contains information on the plankton samples taken at each station. It contains all of the egg data. Fields relevant to these analyses are listed below:

1. CATCHKEY  
2. STATIONKEY  
3. VESSEL  
4. CRUISE  
5. STATION  
6. TAXON  
7. TOTAL\_NUMBER  
8. TOTAL\_WEIGHT

## **Merging Data Tables**

The GOMTrawlfix and GOMCatchnoq data tables can be merged based on 3 fields, CRUISE, VESSEL, and STATION. To further merge the resulting set, the STATIONKEY field must be included in the merge key.

## **Analysis Steps**

The GOMTrawlfix data table, with its station time and place information is the core data table for these analyses. The data table is read into a database file (i.e.,dbf), where the station latitude and longitude values are converted to decimal degrees. The database file is converted to a shapefile for GIS analysis. The records are restricted to VESSEL equal to 4, GEAR\_SIZE equal to 40 (feet), and MESH\_SIZE equal to 1.63 (mm). Next, the GOMCatchnoq data table is read into a database file (i.e.,dbf) and converted into a GIS shapefile, and restricted to records with Vessel equal to 4 (Oregon II). A 10 minute x 10 minute grid was created to cover the area trawled. MINUTES\_FISHED was converted into hours and summed for each 10 minute x 10 minute cell providing trawl effort per cell. TOTAL\_NUMBER of individuals was also summed for each cell for each species analyzed. For each species, mean catch per unit Effort (CPUE) was calculated by dividing

the sum of the TOTAL\_NUMBER of species per cell by the sum of effort trawled (in hours) per cell.

## **Appendix C**

# **Development Scenario for Future Cooling Water Use by New Offshore Facilities in the Gulf of Mexico – Prepared by the Offshore Operators Committee Cooling Water Intake Structure Technical Steering Group**

March 2009

# Development Scenario for CWIS Source Water Biological Baseline Characterization Study

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## Objective

The objective of the development scenario is to provide the basis for estimating water use from regulated cooling water intake structures apportioned among the set of fishery zones (Figure 1) devised for entrainment assessment. This development scenario document recommends a base case of industry activity for assessment of entrainment by new facilities and also provides data for possible consideration of alternative scenarios.

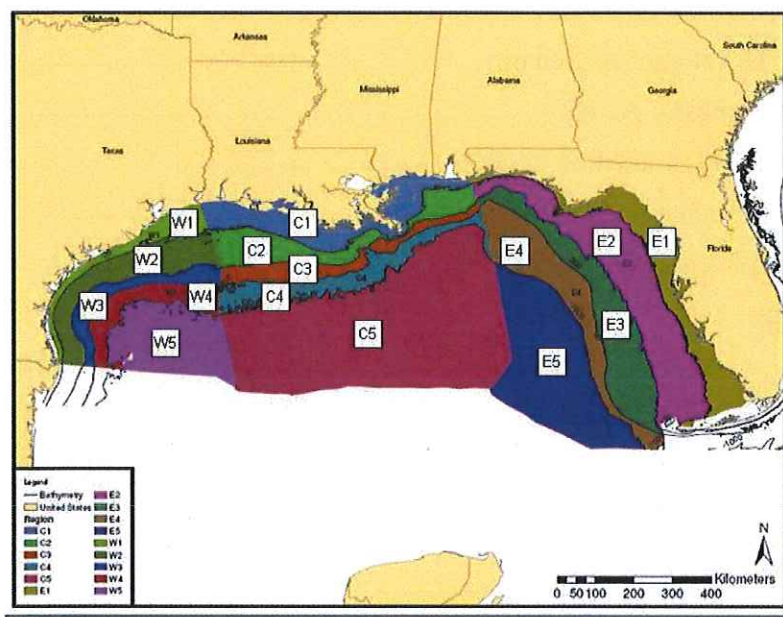


Figure 1. Zones for fishery data and water-use assessment. The depth limits of the zones 1 through 5 correspond, respectively, to 0-20 m, 20-60 m, 60-200 m, and 200-1000 m, and >1000 m (deep GOM).



### Recommended Base Case Development Scenario

Data on the average intake flow rates of various facilities and estimates of the intensity and geographic distribution of industry activity were used to prepare a recommended base case scenario for the estimation of additional seawater intake by regulated facilities (Table 1) that would begin operation by the end of 2011. This time period was chosen so that only integer numbers of facilities would have to be considered.

The remainder of this document discusses the data and rationale used to develop the base case development scenario.

Table 1. Base Case Seawater Use Scenario – Additional Water Use 2009-2011

Fishery Zone	Production Facilities		Drill Ships		Semisubmersible MODU		Jackup MODU	
	Number	Total Water Use (MGD)	Number	Total Water Use (MGD)	Number	Total Water Use (MGD)	Number	Total Water Use (MGD)
C1	0	0	0	0	0	0	0	0
C2	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0
C4	2	7	0	0	1	8	0	0
C5	5	55	5	180	1	8	0	0
E1	0	0	0	0	0	0	0	0
E2	0	0	0	0	0	0	0	0
E3	0	0	0	0	0	0	0	0
E4	0	0	0	0	0	0	0	0
E5	0	0	0	0	0	0	0	0
W1	0	0	0	0	0	0	0	0
W2	0	0	0	0	0	0	0	0
W3	0	0	0	0	0	0	0	0
W4	1	4	0	0	0	0	0	0
W5	1	11	1	36	0	0	0	0

### Geographic Distribution of Industry Activity

Since drilling or production activities must take place in leased areas, the distribution of active leases will provide the base case information for the distribution of industry activity in the various fishery zones. A count of the active leases (Table 2) shows that leasing activity is concentrated in the Central and Western fishery zones, with the deeper water zones (W3-W5 and C3-C5) accounting for 65% of the total leased blocks.

Table 2. Distribution of Leases in the Fishery Data Zones in the Gulf of Mexico

<b>Fishery Data Zones</b>	<b>Number of Total Lease Blocks (Active and Non-Active)</b>	<b>Number of Active Lease Blocks</b>	<b>Fraction of Active Leases (%)</b>
Outside fishery Zones	73		
C1	1312	1016	12.9
C2	1608	950	12.1
C3	1100	668	8.5
C4	1381	926	11.7
C5	7192	2390	30.3
E1	1144	0	0.0
E2	3092	26	0.3
E3	2131	11	0.1
E4	1801	52	0.7
E5	3140	28	0.4
W1	406	212	2.7
W2	1414	433	5.5
W3	792	163	2.1
W4	859	301	3.8
W5	1645	707	9.0

### **Water Use By Drilling Rigs and Production Facilities**

Data on water use by offshore facilities was collected from comments submitted during the Clean Water Act Section 316b Phase III rulemaking and from information submitted by OOC member companies. OOC member companies were asked to submit information on existing production facilities that use more than 2 million gallons per day (MGD) seawater with more than 25% of that used for cooling. The CWIS monitoring requirements apply only to new facilities. Existing facilities are not subject to baseline study or entrainment monitoring requirements. However, information on seawater intake rates was collected to identify facilities that might be used as surrogate (i.e. surrogate for yet-to-be-built new facilities) study sites for entrainment monitoring as well as to characterize seawater intake rates for larger production facilities. The information from both these sources is summarized in Table 3. In the few cases where companies provided information on both maximum and typical daily intake volumes, the typical intake volume was used. Data on production platforms should be considered to be representative only of large offshore production facilities.

Table 3. Seawater Intake Rates for Drilling Rigs and Large Production Facilities

Facility Type	Facility Count for Intake Data	Seawater Intake Rate (MGD)			
		Median	Min	Max	Avg
Production Platform	44	4.6	0.0	58.4	6.3
Jackup Drill Rig	24	6.8	4.2	9.2	6.5
Semisubmersible Drill Rig	11	6.8	0.9	18.0	7.7
Drill Ship	6	40.1	10.0	52.0	36.1

### Geographic Distribution of Production Facilities

Production facility seawater intake data submitted by OOC Member Companies show that although facilities using >2 MGD of seawater can be found in any depth range, facilities are found predominantly (75%) in waters > 200m deep (Table 4). Seawater intakes using >5 MGD are only found in waters >200 m deep. These data are consistent with the expectation that new facilities with large cooling water intakes will be constructed mainly in deeper waters, where the cost of structures provides a strong motivation for the use of hub facilities that process oil and gas from a number of fields. All current production facilities are located in the Western and Central fishery data zones.

Table 4. Distribution of Production Facility Seawater Intakes by Fishery Zone Depth

Fishery Zone Depth (m)	Production Facilities		Production Facility Seawater Intake Rates (MGD)			
	Number	Facilities	Median Usage (mgd)	Average (mgd)	min	max
0-20	3	0.07	1.7	1.6	0.4	2.6
20-60	3	0.07	0.8	2.8	0.7	6.9
60-200	5	0.11	1.7	2.8	0.9	5.0
200-1000	16	0.36	2.8	3.5	0.3	7.2
>1000	17	0.39	6.5	11	1.9	58.4

MMS data on production hub facilities, which process fluids from a number of offshore fields, provide another way of looking at the distribution of facilities that are likely to have seawater intakes in the >2 MGD range. Based on MMS data (MMS, 2008) existing hub facilities are concentrated inside the 300 m isobath with new facilities expected 450 – 2300 m depth range (Figure 2, MMS (2008)).

## DEEPWATER GULF OF MEXICO 2008: AMERICA'S OFFSHORE ENERGY FUTURE

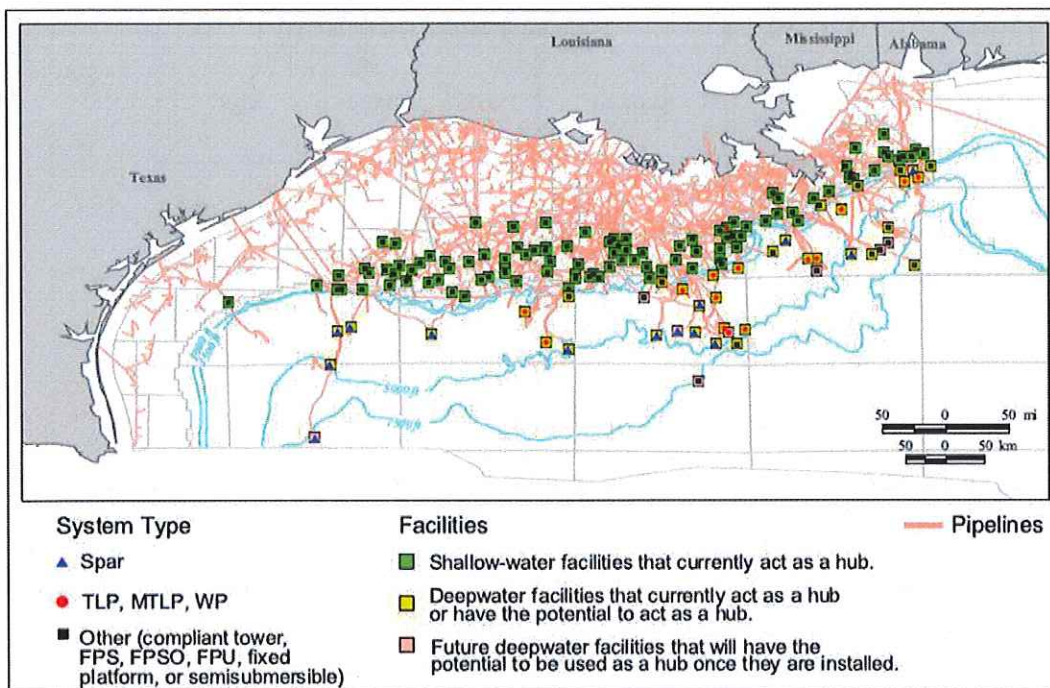


Figure 2. Current and future hub facilities in the Gulf of Mexico (MMS, 2008).

### Number of New Production Facilities Per Year

New facilities subject to CWIS regulations will be added as new Gulf of Mexico resources are put into production. The number of new production facilities is highly dependent on the economic climate and oil prices both of which have recently deteriorated. For the purposes of entrainment assessment, we will use estimates of new facility installations developed by the Minerals Management Service. Given that industry information about planned new investments is often confidential, the MMS estimates represent the most practical approach to estimating the number of facilities that will start production.

The Minerals Management Service (MMS, 2000) estimated that an average of 2 major deepwater production facilities would be commissioned every year (Table 5).

Table 5. Estimated Startups of Deepwater Production Facilities (MMS, 2000)

Year	TLP	Spar	Fixed Platform	Total
2000	1	3		4
2001		2		2
2002	1	1	1	3
2003	1	1		2
2004	1		1	2
2005		1		1
2006		1	1	2
2007	1			1

A later study (MMS, 2008) estimated that an average of 7 projects per year would begin production between 2006 and 2013. Considering that not all new fields will result in the installation of separate production facilities, we will conservatively assume a base case of 3 production facilities per year will start operation for a total of 9 by the end of 2011. The locations of the facilities will be assigned to depth zones 4 and 5 in proportion to the number of active leases in these zones. The average seawater intake rate for each depth zone (Table 4) will be used as the base case.

### Water Use by Drilling Rigs

Information on the water depth capabilities of the Gulf of Mexico drilling rig fleet was obtained from the publicly available Rigzone database ([www.rigzone.com](http://www.rigzone.com)). Based on this information (Table 6) we can develop water depth assumptions for the operation of different types of drilling rigs. Drillships are assumed to operate only in depth zone 5 (>1000 m). Semisubmersible drilling rigs are assumed to operate in zones 4 and 5. Jackup drilling rigs are assumed to operate in depth zones 2 and 3.

New drilling rigs, i.e. rigs for which construction started after July 17, 2006, that enter the GOM fleet are subject to CWIS requirements. Rigzone was commissioned to query their proprietary database for information concerning the expected delivery of new drilling rigs to the GOM fleet. This query revealed (Appendix A) that by the end of 2011, 7 drillships and 10 semisubmersibles will enter service in the GOM fleet. Six of the drillships and two of the semisubmersibles are subject to CWIS requirements. The Rigzone study concluded that it was unlikely that any new-built jackup drilling rigs would enter the Gulf of Mexico fleet by the end of 2011.

The water use of these rigs was divided among the longitudinal zones (i.e. W, C, and E) in proportion to the number of active leases in each zone (Table 2) subject to the restriction that the number of drilling rigs assigned to a zone must be an integer. None of the eastern (E) depth zones accounts for more than 0.7% of the active lease blocks. As a result, the water use by regulated CWIS on drilling rigs was assumed to be zero for all the E depth zones.



Table 6. Summary of the Gulf of Mexico Drilling Rig Fleet

Type of Rig	GOM Rig Fleet			Water Depth Information (m)			
	Total #	In Use February 2009 #	Under Construction for GOM (February 2009) #	Current Drilling <sup>b</sup> MIN	Current Drilling <sup>b</sup> MAX	Rating <sup>c</sup> MIN	Rating <sup>c</sup> MAX
Jackup	77	45	0 <sup>a</sup>	11	82	38	137
Drill Ship	6	6	7	1271	2127	3049	3049
Semisub	27	24	6	215	2475	610	3049

- a. The Rigzone study (Appendix A) concluded that although seven jackups are under construction at U.S. GOM shipyards, all of them are likely to leave the region when they are completed.
- b. Current drilling is the depth at which a rig in use in February 2009 was drilling. Based on information in the publicly available Rigzone.com database.
- c. Rating is the maximum water depth capability of a drilling rig. Based on information in the publicly available Rigzone.com database.

## References

- Richardson, G.E., Nixon, L.D., Bohannon, C., Kazanis, E.G. Montgomery, T.M., Gravois, M.P., (2008); "Deepwater Gulf of Mexico 2008: America's Offshore Energy Future" OCS Report MMS 2008-013 US Minerals Management Service GOM Region  
<http://www.gomr.mms.gov/PDFs/2008/2008-013.pdf>
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## Appendix

### Gulf of Mexico Newbuild Drilling Rigs and Fleet Size Changes

Prepared by Rigzone.com

March 18, 2009



**Gulf of Mexico**  
***Newbuild Rigs and Fleet Size Changes***  
Created March 18, 2009

This report, commissioned by Offshore Operators Committee (OOC), provides analysis and data regarding changes in the size of the jackup, semisubmersible, and drillship fleets in the Gulf of Mexico, with a focus on newbuild rigs that have and will enter the region during the period 2004 to 2014.

## **Introduction and Summary**

The National Pollutant Discharge Elimination System (NPDES) permit for the Western and Central Portions of the Gulf of Mexico (EPA, 2007) requires, under the Clean Water Act Section 316 (b) Phase III regulations, that operators of new facilities with cooling water intake structures (CWIS) that take in more than 2 million gallons per day of seawater with more than 25% of that used for cooling water to undertake source water biological baseline surveys. As defined by the permit, a new facility is one for which construction started after July 17, 2006.

The permit provides operators with the choice of either doing individual site-specific studies to meet some of the permit CWIS requirements or participating in a joint industry study, conducted under a plan to be approved by EPA Region 6, aimed at meeting the requirements. The Offshore Operators Committee (OOC) Environmental Sciences Subcommittee (OOC-ESC) has organized the OOC Cooling Water Intake Structure JIP to address CWIS permit requirements through the joint industry study option. The JIP is reviewing drilling rig and production facility data to estimate the number of cooling water intake structures subject to permit requirements and their respective water intake volumes.

OOC contracted with Rigzone to review the proprietary RigLogix database to estimate the number of new drilling rigs that would enter the Gulf of Mexico fleet over the previous five years and in the next five years. The purpose of this review is to provide the basis for predicting cooling water use by drilling rigs with cooling water intake structures (CWIS) subject to the CWIS requirements.

The conclusions of this review are as follows:

- It is unlikely that any new jackup drilling rigs will enter the GOM fleet by year end 2011.
- Ten newbuild semisubmersible drilling rigs will enter service in the Gulf of Mexico fleet by year-end 2011. Construction of two of these rigs started after July 17, 2006 (Table 1 making them subject to the CWIS regulation.
- Seven newbuild drill ships will enter service in the Gulf of Mexico by year end 2011, Six of the newbuild drill ships were started after July 17, 2006 (Table 1) and are thus subject to CWIS requirements.

## **Gulf of Mexico Drilling Rig Fleet**

In this report, Rigzone addresses the changes in the number of jackups, drillships and semisubmersible rigs working in the Gulf of Mexico over the previous five years and in the next five years. The Offshore Operators Committee commissioned Rigzone to summarize the information according to data gathered in the company's proprietary RigLogix database, which tracks the offshore rig fleet worldwide.

Rigzone and its predecessor companies have been tracking the offshore drilling rig fleet since 1990, and as such the RigLogix database is one of the most comprehensive and detailed rig databases available anywhere in the world. The system includes detailed specifications for more than 1,200 offshore drilling rigs with additional details on their locations, status, and contracts since 2000. This covers both rigs that are currently in service, as well as those that are being built. This system is used by hundreds of offshore operators, service companies, oilfield equipment manufacturers, insurers, financial analysts and other companies to keep track of offshore drilling activity and to help them plan for changes in the market.

#### **Newbuild Rigs Entering the US Gulf of Mexico Between 2004 and 2009**

In the last five years, six newbuild jackups entered the GOM within a year of leaving the shipyard. With water depth capacities ranging from 300 to 550 feet, all of these newbuilds were managed by Rowan. While three of the jackups are still located in the US GOM, three have moved on to other areas worldwide.

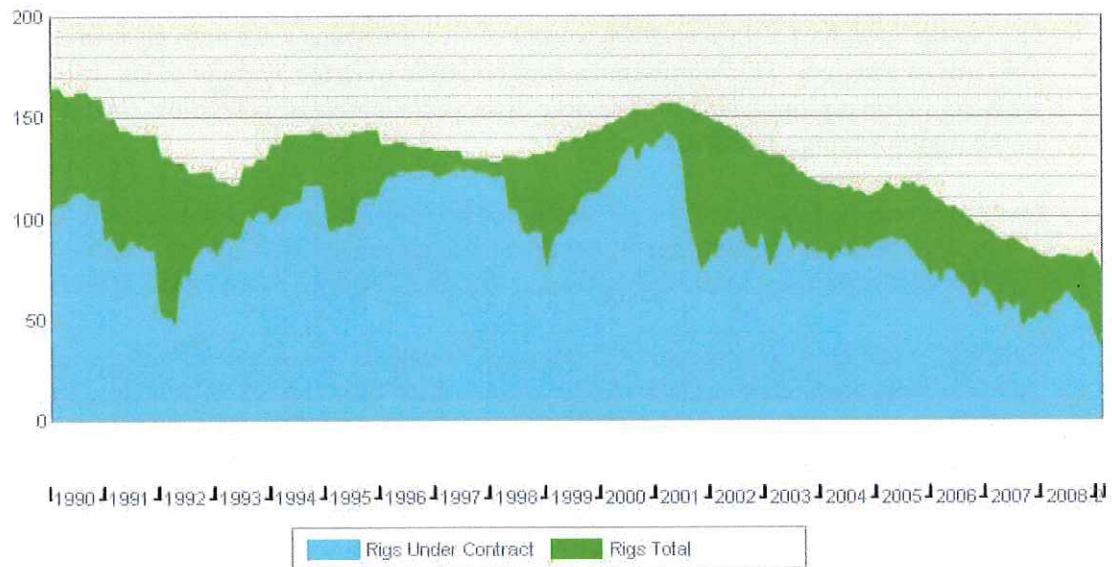
Additionally, three newbuild semisubs entered the US GOM in the last five years, and all of them continue to work in the region. Delivered in early 2005, two of the newbuild semisubs are rated for water depths reaching 7,500 feet deep; while the other semisub was delivered in February 2008 and is rated for 10,000 feet of water.

In the last five years, one newbuild drillship was delivered to the GOM within the first year of leaving the shipyard. Capable of drilling in waters measuring 10,000 feet deep, the Stena DrillMAX was delivered to Repsol for work on Keathley Canyon in January 2008; and the drillship has since moved on to work for Petrobras offshore Brazil.

In all these cases, the existing rigs leaving the US Gulf of Mexico more than offset the newbuilds entering the region. As such, the number of rigs of all three types in the GOM has declined since 2004.

#### **Future Size of the Jackup Fleet**

Currently the Gulf of Mexico jackup rig fleet is undergoing the largest and most long-lasting contraction that it has experienced at any point since the industry downturn of the mid-1980s. Looking back over the last 18 years, the period from 2001 through 2009 has witnessed a 90 rig reduction in the overall jackup fleet size as the number of rigs in the region has fallen from 164 to 74 rigs at the end of February 2009. The chart below illustrates the contracted and total number of jackup rigs in the US Gulf of Mexico during that time period (see "XOM Jackup Util 1990-2009.xls" for supporting data).



With regard to the reduction in the Gulf of Mexico jackup fleet, the losses that the fleet has experienced over the last eight years are largely the result of stronger demand in other regions of the world coupled with the inherent dangers of operating drilling rigs in the Gulf of Mexico. In particular, Hurricanes Ivan, Katrina, Rita, and Ike combined to destroy a total of 11 jackups while sending many more to the shipyards for extensive repairs. This risk combined with the lucrative long-term contracts to be found in other regions, particularly the Persian Gulf, has driven many rig managers to relocate their jackups to other regions.

Given the unprecedented contraction and historically low utilization rates for jackup rigs in the US Gulf of Mexico, there is very little chance that the jackup rig fleet will expand at any point during the next several years. In fact, by the end of 2009, six more active jackups are expected to leave the US Gulf of Mexico for Mexico, Canada and the Mediterranean. The seven jackups that are under construction at shipyards on the US Gulf Coast are not contracted yet, but are all likely to leave the region when they are completed. If these rigs do not land contracts, then they may stack at ports along the US Gulf Coast.

**Conclusion: Expected Growth in Total Jackup Fleet By Year End 2011: -13 rigs or more**

### **Future Size of the Drillship Fleet**

During the month of February 2009, a total of five drillships were actively working in the US Gulf of Mexico. This represents a slight decline over the average of six drillships working in the region during the previous four years, and it is well below the peak of 9 rigs in the region during Q2 2004.

Over the course of the next 2 years, seven newbuild drillships are contracted to enter the US Gulf of Mexico. In addition, Transocean's Deepwater Pathfinder is scheduled to move into the US GOM from West Africa during March 2010 for a 5-year contract with ENI.

One active drillship, Transocean's Discoverer Enterprise, is contracted through the end of 2010 for work in the US Gulf of Mexico, after which time it is likely to leave, although the possibility remains that the rig might have its contract extended. That results in a net increase of seven drillships working in the Gulf of Mexico over the next two years. Please see "XOM Drillship Util 2004-2014.xls" and "Gantt - GOM DS SS - 2009-2014.xls" for details.

**Conclusion: Expected Growth in Total Drillship Fleet By Year End 2011: +7 rigs**

### **Future Size of the Semisubmersible Fleet**

During February 2009, a total of 27 semisubmersible rigs were in the waters of the US Gulf of Mexico, of which 24 were under contract for work. This is just below the average of 25 rigs under contract in the region seen over the previous five years, and it is 20% below the peak of 30 semisubs contracted in the GOM which was seen in June 2007.

By mid-2010 a total of nine new deepwater semisubmersible rigs are contracted to move into the Gulf of Mexico. In addition, one further semisub, the ENSCO 8503, is scheduled to arrive in the US GOM during 2011 to make a total of ten newbuild semisubs moving into the region within the next two years.

On the other hand, three semisubs currently in the US GOM are scheduled to leave the region this year. A further five semisubs in the US Gulf of Mexico have contracts ending by April 2010. Of these five rigs with expiring contracts, four belong to Diamond Offshore which has contracted similar rigs to start work in 2009 for OGX offshore Brazil. Therefore, it would not be surprising to see some or all of these rigs move to other regions. A conservative assumption would be that two or three of them will leave the GOM for work elsewhere. However, probably the most likely scenario for these rigs is that most of them will not land new contracts and end up stacking in the Gulf of Mexico waiting for higher levels of rig demand.

As such, the total reduction in the number of semisubs in the Gulf of Mexico would be at least three but likely four or five. Combined with the ten incoming newbuild semisubmersibles, the Gulf of Mexico should see a net increase of six semisubs.

**Conclusion: Expected Growth in Total Semisub Fleet By Year End 2011: +6 rigs**



### **Summary of New Drilling Rigs Entering The Gulf of Mexico Fleet by 2011**

The cooling water intake structure requirements apply only to facilities for which construction started after July 17, 2006. Table 1 summarizes the construction start dates and anticipated delivery dates for drilling rigs expected to enter the Gulf of Mexico fleet by year-end 2011.

**Table 1. Construction Start and Delivery Dates for Semisubmersible Drilling Rigs and Drillships**

Type of Rig	Started (Mon-YY)	Delivery (Mon-YY)	Rig Owner	Rig
Drillship	March-06	July-09	Transocean Inc.	Discoverer Clear Leader
Drillship	June-06	July-09	Transocean Inc.	Discoverer Americas
Drillship	September-06	March-10	Transocean Inc.	Discoverer Inspiration
Drillship	April-07	April-10	Pride International	Pride Drillship TBN 1
Drillship	June-07	January-10	Frontier Drilling AS	Bully 1
Drillship	July-07	September-10	Pride International	Pride Drillship TBN 2
Drillship	December-07	June-11	Vantage Energy Services	Titanium Explorer
Semisubmersible	January-02	July-07	Noble Drilling	Noble Danny Adkins
Semisubmersible	January-02	April-10	Noble Drilling	Noble Jim Day
Semisubmersible	May-05	April-09	Maersk Drilling	Maersk Developer
Semisubmersible	August-05	May-09	Larsen O&G	PetroRig I
Semisubmersible	September-05	April-09	ENSCO	ENSCO 8500
Semisubmersible	January-06	September-09	ENSCO	ENSCO 8501
Semisubmersible	March-06	June-09	Transocean Inc.	GSF Development Driller III
Semisubmersible	March-06	March-10	Saipem	Scarabeo 9
Semisubmersible	September-06	April-10	ENSCO	ENSCO 8502
Semisubmersible	June-07	November-10	ENSCO	ENSCO 8503

### **Reference**

EPA(2007); "[FRL-8323-5] Notice of Final NPDES General Permit; Final NPDES General Permit for New and Existing Sources and New Dischargers in the Offshore Subcategory of the Oil and Gas Extraction Category for the Western Portion of the Outer Continental Shelf of the Gulf of Mexico (GMG290000) ", 72 Federal Register 109 pp 31565-31578 Accessed at <http://epa.gov/region6/water/npdes/genpermt/index.htm#GeneralPermit> on 10/29/07

## **Appendix D**

### **Life-History Summary Tables**

## Cooling Water Intake Structure Biological Baseline Study

Table D1. Stage, stage duration, and estimated mortality rates for brown shrimp. See text for additional information.

Stage	Variable	Case	Value	Comments
Eggs	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	1.8971	Reitsema et al. (1982) reported brown shrimp that averaged 192 mm T.L. released an average of 246,000 viable eggs of which 15% hatched ( $S = 0.15$ ), $M = -\ln(S)$ or $1.8971\ d^{-1}$ .
		Low	1.8971	As above.
		High	1.8971	As above.
	Stage Duration (Days)	Base	0.67	Eggs are demersal and hatch within 24-h after release (Pattillo and Czapla 1997 and references therein). Cook and Lindner (1970) note that in the laboratory the eggs usually hatch within 14 to 18 h. 16 h is the median which is 0.67 d.
		Low	0.58	Low end of the 14-18 h hatch time given by Cook and Lindner (1970).
		High	0.75	High end of the 14-18 h hatch time given by Cook and Lindner (1970).
Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.1308	Cook and Murphy (1966) reported that 219 of 1,200 brown shrimp larvae feed on diatoms during early development and brine shrimp at later stages survived to the last mysis stage which occurred 13 days after the start of the experiment. $S = 219 \div 1,200 = 0.1825$ ; $M = -\ln(S) = 1.7010$ . Daily value = $1.7010 \div 13 = 0.1308\ d^{-1}$ .
		Low	0.1308	As above.
		High	0.1308	As above.
	Stage Duration (Days)	Base	13.33	As reported (13 d) by Cook and Murphy (1966) based upon laboratory studies. Added 0.33 to make the egg and larval stages a total of 14 days.
		Low	10.42	Lassuy (1983a) and references therein report larvae pass through 5 naupliar, 3 protozoel and 3 mysis stages over a 10 to 25 day period before transforming into postlarvae. Added 0.42 to make egg and larval stages a total of 11 days.
		High	25.25	See above. Added 0.25 to make egg and larval stages a total of 26 days.

# Cooling Water Intake Structure Biological Baseline Study

Table D1. Continued.

Stage	Variable	Case	Value	Comments
Early Post Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.0113	Total stage mortality of 1.7 reported by EPA (2002) based upon Costello and Allen (1970). Total stage duration is estimated at 151 d (below). $M = 1.7 \div 151 = 0.0113\ d^{-1}$ . This stage occurs during fall and winter when temperatures are low and growth is slow but survival is high. Post larvae may spend extensive time burrowed in the sediments.
		Low	0.0113	As above.
		High	0.0113	As above.
	Stage Duration (Days)	Base	151	Extended duration of the early postlarvae stage based on Temple and Fischer (1967) and offshore abundance of this stage as reported in the LOOP studies (Sasser and Visser 1999).
		Low	151	As above.
		High	151	As above.
	Late Post-Larvae/Early Juvenile	Base	0.0320	Minello et al. (1989) based upon the average of four cohorts in a Galveston Bay salt marsh.
		Low	0.0234	Lowest cohort value observed by Minello et al. (1989).
		High	0.0554	Highest cohort value observed by Minello et al. (1989).
		Base	61	Based upon the average of the maximum-minimum size at the end and start of the cohort analysis conducted by Minello et al. (1989) divided by an estimated growth of 1 mm/day.
		Low	47	Minimum value derived from the Minello et al. (1989) study.
		High	72	Maximum duration derived from the et al. (1989) study.

# *Cooling Water Intake Structure Biological Baseline Study*

Table D1. Continued.

Stage	Variable	Case	Value	Comments
Sub Adult/Adult	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.0092	Shrimp stock assessment base value (pers. comm., J. Nance, NOAA/NMFS, Galveston Laboratory, TX).
		Low	0.0067	Lower end of range in shrimp stock assessment (pers. comm., J. Nance, NOAA/NMFS, Galveston Laboratory, TX).
		High	0.0117	Upper end of range in shrimp stock assessment (pers. comm., J. Nance, NOAA/NMFS, Galveston Laboratory, TX).
	Stage Duration (Days)	Base	139	Balance of year given the above durations of earlier life stages.
		Low	156	Balance of year given the above durations of earlier life stages.
		High	116	Balance of year given the above durations of earlier life stages.
Total Subadult/ Adult Fishing Mortality		Base	1.3939	Ratio of F:M based upon Gazey et al. (1982a, b) = $0.0279 \div 0.0256 = 1.09$ . $M$ = daily instantaneous mortality (0.0092) x stage duration (139 days) = 1.2788. $F = 1.09 (M) = 1.3939$ .
		Low	1.1393	Ratio of F:M based upon Gazey et al. (1982a, b) = $0.0279 \div 0.0256 = 1.09$ . $M$ = daily instantaneous mortality (0.0067) x stage duration (156 days) = 1.0452. $F = 1.09 (M) = 1.1393$ .
		High	1.4793	Ratio of F:M based upon Gazey et al. (1982a, b) = $0.0279 \div 0.0256 = 1.09$ . $M$ = daily instantaneous mortality (0.0117) x stage duration (116 days) = 1.3572. $F = 1.09 (M) = 1.4793$ .

## *Cooling Water Intake Structure Biological Baseline Study*

Table D2. Stage, stage duration, and estimated mortality rates for white shrimp. See text for additional information.

Stage	Variable	Case	Value	Comments
Eggs	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	1.8971	As per brown shrimp (Gallaway 2005). (Although spawning occurs in the water column, white shrimp eggs sink to the bottom. Ensuing larval stages are planktonic.)
		Low	1.8971	As above.
		High	1.8971	As above.
	Stage Duration (Days)	Base	0.46	Klima et al. (1982) reported that eggs hatch into planktonic nauplii larvae within 10 to 12 hours after fertilization. Mean duration = 0.46 d.
		Low	0.42	Low end of the 10-12 h hatch time given by Klima et al. (1982).
		High	0.50	High end of the 10-12 h hatch time given by Klima et al. (1982).
Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.1308	As per brown shrimp (Gallaway 2005).
		Low	0.1308	As above.
		High	0.1308	As above.
	Stage Duration (Days)	Base	13.33	As per brown shrimp (Gallaway 2005).
		Low	10.42	As per brown shrimp (Gallaway 2005).
		High	25.25	As per brown shrimp (Gallaway 2005).
Early Post Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.2429	Derived by Gallaway (2005).
		Low	0.2429	As above.
		High	0.2429	As above.
	Stage Duration (Days)	Base	7	Derived by Gallaway (2005).
		Low	6	Derived by Gallaway (2005).
		High	8	Derived by Gallaway (2005).



Table D2. Continued.

Stage	Variable	Case	Value	Comments
Late Post-Larvae/Early Juvenile	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	0.0320	As per brown shrimp (Gallaway 2005).
		Low	0.0234	As per brown shrimp (Gallaway 2005).
		High	0.0554	As per brown shrimp (Gallaway 2005).
	Stage Duration (Days)	Base	61	As per brown shrimp (Gallaway 2005).
		Low	47	As per brown shrimp (Gallaway 2005).
		High	72	As per brown shrimp (Gallaway 2005).
Sub Adult/Adult	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	0.0092	As per brown shrimp (Gallaway 2005).
		Low	0.0067	As per brown shrimp (Gallaway 2005).
		High	0.0117	As per brown shrimp (Gallaway 2005).
	Stage Duration (Days)	Base	283.7	Balance of year given the above durations of earlier life stages.
		Low	301.6	Balance of year given the above durations of earlier life stages.
		High	259.8	Balance of year given the above durations of earlier life stages.
Total Subadult/Adult Fishing Mortality		Base	1.5921	Ratio of F:M based upon Gazey et al. (1982a, b) = $0.0203 + 0.0334 = 0.61$ . Daily instantaneous mortality (0.0092) x stage duration (283.7 days) = 2.610. F = 0.61 (M) = 1.3939
		Low	1.2326	Ratio of F:M based upon Gazey et al. (1982a, b) = $0.0203 + 0.0334 = 0.61$ . Daily instantaneous mortality (0.0067) x stage duration (301.6 days) = 2.0207. F = 0.61 (M) = 1.2326
		High	1.8542	Ratio of F:M based upon Gazey et al. (1982a, b) = $0.0203 + 0.0334 = 0.61$ . Daily instantaneous mortality (0.0117) x stage duration (259.8 days) = 1.0340. F = .61 (M) = 1.8542.

## Cooling Water Intake Structure Biological Baseline Study

Table D3. Menhaden life history parameters and the basis for their selection.

Stage	Variable	Case	Value	Reference & Comments
Egg	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	1.044	EPA (2002)
		Low	1.044	EPA (2002)
		High	6.21	EPA (2002)
	Stage Duration (Days)	Base	1.75	$e^2M$ (2005) and references therein. Mean of 1.5 d for Gulf menhaden and 2.0 d for yellow menhaden.
		Low	1.5	$e^2M$ (2005) and references therein. Lower limit of Gulf/yellow menhaden range.
		High	2.0	$e^2M$ (2005) and references therein. Upper limit of Gulf/yellow menhaden range.
Larvae	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	0.059	$e^2M$ (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.).
		Low	0.0488	$e^2M$ (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.).
		High	0.077	$e^2M$ (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.).
	Stage Duration (Days)	Base	65	$e^2M$ (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.).
		Low	60	$e^2M$ (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.).
		High	60	$e^2M$ (2005) based on Deegan and Thompson (1987) and Rose (2004; pers. comm.).
Juvenile 1	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	0.013	$e^2M$ (2005) based on Deegan (1990).
		Low	0.013	$e^2M$ (2005) based on Deegan (1990).
		High	0.013	$e^2M$ (2005) based on Deegan (1990).
	Stage Duration (Days)	Base	298.25	365 days minus the sum of earlier life-history durations.
		Low	303.5	365 days minus the sum of earlier life-history durations.
		High	303	365 days minus the sum of earlier life-history durations.

## Cooling Water Intake Structure Biological Baseline Study

Table D4. Stage, stage duration, and estimated mortality rates for the blue crab. See text for additional information.

Stage	Variable	Case	Value	Comments
Egg	-	-	-	The egg stage is not relevant. Females retain egg masses until they hatch as zoea.
Larvae (Zoea-Early Juvenile)	Daily instantaneous mortality ( $M\ d^{-1}$ )	Base	0.3000	EPA (2002) reported total mortality for these stages combined was 13.8 citing Rose and Cowan (1993). On average these stages occur over a 46-d period. Daily rate = $13.8 \div 46 = 0.3000\ d^{-1}$ .
		Low	0.3000	As above.
		High	0.3000	As above.
	Stage duration (days)	Base	46	Pattillo et al. (1997) reports 31-43 days for development through seven zoeal stages and that 6-12 days were required to develop through the megalopal stage to the first juvenile crab stage. Thus, the total period was from 37-55 days. We used the median 46 days as the base case.
		Low	37	Lower limit of Pattillo et al. (1997).
		High	55	Upper limit of Pattillo et al. (1997).
	Daily instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.0027	EPA (2002) used an annual rate of $M = 1.0\ d^{-1}$ which equates to a daily rate of 0.002739.
		Low	0.0027	As above.
		High	0.0027	AS above.
Juvenile/Adults	Stage duration (days)	Base	319	Balance of year given the 46-d duration of larval life stages.
		Low	328	Balance of year given the 37-d duration of larval life stages.
		High	310	Balance of year given the 55-d duration of larval life stages.

## Cooling Water Intake Structure Biological Baseline Study

Table D5. Red snapper life history parameters and the basis for their selection. See text for additional information.

Stage	Variable	Case	Value	Reference & Comments
Egg	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.4984	The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999).
		Low	0.4984	The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999).
		High	0.4984	The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999).
	Stage Duration (Days)	Base	1	$e^2M$ (2005) and references therein.
		Low	1	$e^2M$ (2005) and references therein.
		High	1	$e^2M$ (2005) and references therein.
Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.2413	Based upon the derivations of Gallaway et al. (2007) with revisions by Gallaway et al. (2009)- see text. Total stage mortality of $6.7564 \div 28\ \text{days} = 0.2413\ d^{-1}$ .
		Low	0.2599	Total stage mortality of $6.7564 \div 26\ \text{days}$ (stage duration) = $0.2599\ d^{-1}$ .
		High	0.2252	Total stage mortality of $6.7564 \div 30\ \text{days}$ (stage duration) = $0.2252\ d^{-1}$ .
	Stage Duration (Days)	Base	28	Rooker et al. (2004) estimated settlement at 16-19 mm or 27-30 d. Szedlmayer and Conti (1999) suggested metamorphosis occurred at 18 mm or 26 d. The median of 28 d represents the base case.
		Low	26	Lower estimate of Rooker et al. (2004) and Szedlmayer and Conti (1999).
		High	30	Lower estimate of Rooker et al. (2004) and Szedlmayer and Conti (1999).
Juvenile 1	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.1196	Based on Gallaway (2005) and Rooker et al. (2004), the estimated $M = 0.1196\ d^{-1}$ .
		Low	0.1010	Lower 95% Confidence Limit of Gallaway (2005).
		High	0.1382	Upper 95% Confidence Limit of Gallaway (2005).
	Stage Duration (Days)	Base	38	Based upon the derivations of Gallaway (2005) - see text.
		Low	36	Gallaway (2005).
		High	40	Gallaway (2005).

Table D5. Continued.

Stage	Variable	Case	Value	Reference & Comments
Juvenile 2	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.0055	Based upon Gazey et al. (2008) estimate of $M = 2.0$ . Daily instantaneous mortality $M = 2.0 \div 365\ days = 0.0027\ d^{-1}$ .
		Low	0.0055	As above.
		High	0.0055	As above.
	Stage Duration (Days)	Base	117	Defined as red snapper from 66 days old to the end of the year. The period July-December includes 183 days which minus 66 days results in a stage duration of 117 days.
		Low	121	183 days - 62 days (sum of low case larvae and juvenile 1 stage durations) = 121 days.
		High	113	183 days - 70 days (sum of high case larvae and juvenile 1 stages) = 113 days.
Juvenile 3	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.0032	Based a annual mortality rate $M = 1.2$ from Gazey et al. (2008). Dividing 1.2 by 365 days yields $M = 0.0032\ d^{-1}$ .
		Low	0.0032	As above.
		High	0.0032	As above.
	Stage Duration (Days)	Base	181	Remainder of year 1.
		Low	181	Remainder of year 1.
		High	181	Remainder of year 1.

Table D6. Yellowfin tuna life history parameters and the basis for their selection. See text for additional information.

Stage	Variable	Case	Value	Reference & Comments
Egg	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	3.54	Based upon the temperature egg mortality model of Pepin (1991).
		Low	3.54	Same as above.
		High	3.54	Same as above.
	Stage Duration (Days)	Base	1.34	Margulies et al. (2007) found that the egg stage duration for yellowfin tuna ranged from 20 to 28 h (0.83-1.17 d) depending upon water temperature (range 24.0-29.5°C). Harada et al. (1980 cited in Pauley and Pullin 1988) reported egg stage durations of 1.34-1.85 depending on temperature (range 18.7-30.1°C). Median value of these values = 1.34.
		Low	0.83	Lower limit of studies described above
		High	1.85	Upper limit of studies described above
Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.33	Pooled $M$ of yellowfin larvae collected in the northern GOM (Lang et al. 1994, Grimes and Lang 1992).
		Low	0.16	Low end of range reported by Lang et al. (1994). Grimes and Lang (1992) reported a lower $M = 0.27\ d^{-1}$
		High	0.45	High end of range reported by Lang et al. (1990). Grimes and Lang (1992) reported an upper $M = 0.41\ d^{-1}$
	Stage Duration (Days)	Base	16	Mean of Lang et al. (1990) and Wexler et al. (2007)
		Low	12	Low end of range reported by Lang et al. (1994) for yellowfin larvae collected in the northern GOM
		High	20	Upper end of age range reported by Wexler et al. (2007) for Pacific yellowfin



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Table D7. Red drum life history parameters and the basis for their selection. See text for additional information.

Stage	Variable	Case	Value	Reference & Comments
Egg	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.4984	The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999).
		Low	0.4984	The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999).
		High	0.4984	The value for Atlantic croaker in the Gulf of Mexico from Diamond et al. (1999).
	Stage Duration (Days)	Base	1	$e^2M$ (2005) and references therein.
		Low	1	$e^2M$ (2005) and references therein.
		High	1	$e^2M$ (2005) and references therein.
Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.3009	Comyns (1997) best estimate of larval mortality was $0.33\ d^{-1}$ ( $SE = 0.04$ ) and covered larvae in the 2.0 to 5.0 mm size range Rooker et al. (1999) estimated juvenile mortality (8 to 20 mm) to be $0.1365\ d^{-1}$ . Linear extrapolation between $0.33\ d^{-1}$ and $0.1365\ d^{-1}$ yields a daily value of $0.23325\ d^{-1}$ which was used for larvae between 6 and 8 mm. The composite of the two rates yields a value of $0.3009\ d^{-1}$ .
		Low	0.2225	Base value minus 95% CI based upon a SE of 0.04 (Comyns 1997).
		High	0.3793	Base value plus 95% CI based upon a SE of 0.04 (Comyns 1997).
	Stage Duration (Days)	Base	22	Rooker et al. (1999) observed peak densities of benthic settlers occurred for individuals 8-9 mm with corresponding ages of 20 to 24 days. For the base case we used the median value of 22 days at settlement to approximate the base-case length of the plankton period.
		Low	20	Low end of the range observed by Rooker et al. (1999).
		High	24	High end of the range observed by Rooker et al. (1999).

# Cooling Water Intake Structure Biological Baseline Study

Table D7. Continued.

Stage	Variable	Case	Value	Reference & Comments
Juvenile 1	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	0.1365	This stage consists of early juveniles of red drum that have settled into benthic habitats at an age of 20-24 d. In Figure 4 of Rooker et al. (1999), settled juvenile 1 drum covers a size range from 8 to 20 mm SL. Observed Z for this size range was 0.134 $d^{-1}$ in 1994 and 0.139 $d^{-1}$ in 1995 (Rooker et al. 1999). We used the mid-point between these two Z values as the base-case estimate. Agreement with $e^2m$ (2005).
		Low	0.134	Low Z observed by Rooker et al. (1999). Agreement with $e^2m$ (2005).
		High	0.139	High Z observed by Rooker et al. (1999). Agreement with $e^2m$ (2005).
	Stage Duration (Days)	Base	18.5	This stage consisted of individuals up to 24 mm total length (Rooker et al. 1999). In 1994, 24-mm long fish were 41 days in age whereas in 1995, 24-mm long red drum were about 44 days old. Age at settlement in 1994 was about 21 days indicating a stage duration of 20 days (Rooker et al. 1999). In 1995, age at settlement was about 27 days, indicating a stage duration of about 17 days. For the base case we used a stage duration of 18.5 days, the median value.
		Low	17	Low duration observed by Rooker et al. (1999).
		High	20	High duration observed by Rooker et al. (1999).

## Cooling Water Intake Structure Biological Baseline Study

Table D7. Continued.

Stage	Variable	Case	Value	Reference & Comments
Juvenile 2	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	0.0094	Median mortality rates derived from Figure 4 in Scharf (2000) for Galveston and Sabine Lake Estuaries, Dec.-Mar.
		Low	0.0079	Galveston Bay mortality rate (Dec.-Mar.) derived from Figure 4 in Scharf (2000).
		High	0.0108	Sabine Lake mortality rate (De-Mar.) derived from Figure 4 in Scharf (2000).
	Stage Duration (Days)	Base	168.5	Based on Scharf (2000) we estimated this stage extends from October-March (180 days). Above we have accounted for 41.5 days (from egg to the juvenile 1 stage) which occur in the September/October period. Thus, for the base case, the duration of the juvenile 2 stage is estimated at 168.5 days (180 days-11.5 days in October).
		Low	172	In the low case above, egg to the juvenile 1 stage occurs over a total of 38 days (September plus 8 days in October). The stage duration for the low duration estimate is 180 days-8 or 172 days.
		High	165	Similarly, the high case described above extends for 45 days. This would allocate 15 days in October; 180-15 yields a stage duration of 165 days.
Juvenile 3	Daily Instantaneous Mortality ( $M d^{-1}$ )	Base	0.0018	Red drum stock assessment value used for age 0 (Porch 2000).
		Low	0.0018	Red drum stock assessment value used for age 0 (Porch 2000).
		High	0.0018	Red drum stock assessment value used for age 0 (Porch 2000).
	Stage Duration (Days)	Base	155	Remainder of year 1.
		Low	155	Remainder of year 1.
		High	155	Remainder of year 1.

Table D8. Adult red drum annual mortality rates. Source EPRI (2005).

Parameter/Age	Stage Mortality
M (annual)	
Ages 1-5	0.23
Ages 6-12	0.13
F (annual)	
Age 1	0.16
Age 2	0.49
Age 3	0.62
Age 4	0.63
Age 5	0.39
Age 6+	0.39

Table D9. Bay anchovy life history parameters and the basis for their selection.

Stage	Variable	Case	Value	Reference & Comments
Egg	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	1.044	$e^2M$ (2005) citing EPRI (2005) and PSEG (1999).
		Low	0.69	$e^2M$ (2005) citing Houde (1987).
		High	1.94	$e^2M$ (2005) citing Lowestoft (2000; actual citation is Bunn et al. 2000).
	Stage Duration (Days)	Base	1	$e^2M$ (2005) citing Robinette (1983) and Houde (1987).
		Low	1	$e^2M$ (2005) citing Robinette (1983) and Houde (1987).
		High	1	$e^2M$ (2005) citing Robinette (1983) and Houde (1987).
Larvae	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.2059	$e^2M$ (2005) citing Houde (1987).
		Low	0.1804	$e^2M$ (2005) citing Houde (1987).
		High	0.231	$e^2M$ (2005) citing EPRI (2005) and PSEG (1999).
	Stage Duration (Days)	Base	34	$e^2M$ (2005) citing EPRI (2004) and PSEG (1999).
		Low	30.63	$e^2M$ (2005) citing EPRI (2005) and PSEG (1999).
		High	34	$e^2M$ (2005) citing EPRI (2005) and PSEG (1999).
Juvenile 1	Daily Instantaneous Mortality ( $M\ d^{-1}$ )	Base	0.004	$e^2M$ (2005) citing EPRI (2005) and PSEG (1999).
		Low	0.004	$e^2M$ (2005) citing EPRI (2005) and PSEG (1999).
		High	0.01	$e^2M$ (2005) citing Houde (1987).
	Stage Duration (Days)	Base	330	365 days minus the sum of earlier life-history durations.
		Low	333.4	365 days minus the sum of earlier life-history durations.
		High	330	365 days minus the sum of earlier life-history durations.

# **ADDENDUM (REVISED)**

## **GULF OF MEXICO COOLING WATER INTAKE STRUCTURE: SOURCE WATER BIOLOGICAL BASELINE CHARACTERIZATION STUDY**

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for

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## **INTRODUCTION**

The Offshore Operators Committee's (OOC) Contract 2008-08-01 with LGL Ecological Research Associates, Inc. (LGL) was modified to enable LGL to conduct additional analyses of SEAMAP data as an addendum to the OOC Task 1 Final Project Report "Gulf of Mexico Cooling Water Intake Structure: Source Water Biological Baseline Characterization Study". The objectives of the analyses were to 1) calculate average total density for fish eggs and larvae (all species combined) by a) fishery zone and b) for larvae, total density by month of sampling and zone; and 2) provide species composition and density data for each geographic zone based upon data for all years combined. Background data for these analyses can be found in the referenced final report.

It should be noted that the analyses describing total larvae and egg densities by region and total larval densities by month and region are based on the same sample screening protocols specified in the final report referenced above (samples where both eggs and larvae were analyzed from a sample) whereas all available samples were used to calculate an alternative mean total larvae density estimate by region and to describe the species composition data for each region.

The results of the Source Water Biological Baseline Study were presented to the Environmental Protection Agency on 24 August 2009, and the draft final report was subjected to additional review following this presentation. The major comments included the request that the assessment report describe and evaluate those species most susceptible to impingement and entrainment and provide more information regarding impacts on forage species. The original Addendum provided data listings enabling the requested assessments, however, we have revised the Addendum to specifically address these issues as requested.

## **METHODS**

A list of the 10 most abundant species was extracted from the overall taxa lists for each of the regions in which new developments are expected (C4, C5, W4, W5). Forage species were identified within these lists. The approach outlined by Gallaway et al. (2007) was used to assess the overall impacts of the new facilities on ecosystem components for which the life-history data were insufficient to support species-specific modeling approaches. In this approach, estimated entrainment losses are compared with the "population" of a larger "reference parcel" or control volume of water. This approach was originally developed to estimate effects of entrainment for proposed Ocean Thermal Energy Conversion projects (e.g., Sinay-Friedman and Reitzel 1980). The control volume consists of one-half the volume of a cylinder of water having a radius equivalent to the distance within approximately 1-day's transport of the intake based upon estimates of median current speed for the region. For the four regions where new development is expected the median current speed for winter and summer are on the order of 0.36 m/s and 0.31 m/s, respectively (Minerals Management Service Gulf of Mexico Region Visual No. 6: Oceanography, Accidents and Vegetation, 1983). The depth of the control volume cylinder was set at 200 m which corresponds to the maximum depth of SEAMAP sampling in deep water in these regions. Most of the new intake structures would also be expected to be located within this

depth range or shallower. One-half the Control Volume (C.V.) was calculated in million m<sup>3</sup> for each season:

$$C.V. = \frac{\pi r^2 h}{1,000,000} \times 0.5$$

where r = radius was estimated in m based on median seasonal current speeds, and h (height) was set at 200 m. Based on the median current speed of 0.36 m/s, the cylinder radius r for the winter season was 31,104 m. For the summer season, r was 26,784 m based on the reported median current speed 0.31 m/s.

For assessment purposes, we took the conservative approach of treating the cumulative total intake of all facilities as if it were a single, large facility. In fact, the individual intakes would each be assessed against the control volume and summed. The total daily seawater use in million

m<sup>3</sup> was divided by one-half of the control volume of water passing by the site each day. Assuming a uniform density distribution, the estimated numbers of ichthyoplankton removed on a daily basis would be equivalent to the water-use estimates (i.e., the ichthyoplankton population in the control volume would be estimated by multiplying the volume by the same density estimates used in the entrainment analysis).

## **RESULTS**

Larval and egg densities by region and month-by-region are shown by Tables 1-3. These estimates are restricted to only those collections where both eggs and larvae were analyzed for a sample. In many samples, egg counts were not made. On a regional basis (Table 1), sample sizes (i.e., tows) ranged from a low of 51 (Region W4) to a high of 778 (Region C5). Both the larvae and egg density data show pronounced decrease with depth in all regions, especially in depth zones 4 and 5 as compared to shallower depths. Most or all new CWIS facilities identified in the final report are projected to occur in depth zones 4 and 5.

Larvae (Table 2) and egg density (Table 3) by month and zone for depth zones where new CWIS development is projected are not only low, as compared to shallower depths, but reflect a much smaller level of monthly variation as compared to that seen for shallower depths. For example, mean larval density in the C1 Region ranged from 0.12 larvae/m<sup>3</sup> in February to 23.1 larvae/m<sup>3</sup> in July. In contrast, larval density in C5 ranged from 0.13 in March to a high of 0.77 in September. Monthly egg densities in C1 ranged from 1.0 egg/m<sup>3</sup> in December to about 20 eggs/m<sup>3</sup> in March and August (see Table 3). Egg densities in C5 never reached as high as 1 egg/m<sup>3</sup>.

Table 4 provides larvae density results based on all samples collected. Sample size by region ranged from 98 (W4) to 1,036 (C5) tows. Larval density patterns were similar to those estimated from the more restricted dataset (compare Table 1 and Table 4). Larval density based on the total samples available show pronounced decreases with depth, especially in depth zones 4 and 5 as compared to shallower depths.

The most abundant taxa in zones where new CWIS development is expected to occur are dominated by forage species (Table 5, complete species composition data are provided in Attachment 1). Region C5 reflected the highest number of total taxa (457) and the top 10 species comprised over 64% of the total density. The number of taxa in each region ranged from a low of 244 (W4) to the high of 457 taxa observed for Region C5. In all cases, the top 10 species comprised over 60% of the total density. Lanternfishes (*Myctophidae*) and bristlemouth (*Gonostomatidae*) typically dominated the forage species represented in the collections.

Lanternfishes are small, deep sea fish that are represented by 246 species in 33 genera and occur in oceans worldwide. They are named after their conspicuous use of bioluminescence. Alexander (1998) suggests that lanternfishes account for as much as 65% of all deep sea fish biomass. Global biomass is estimated to be on the order of 550 to 660 million metric tonnes, several times the entire world's fisheries catch.

Larval myctophids are non-migratory, spending day and night in near surface waters (Ahlstrom 1959). Diel vertical migration is first evident at or shortly after metamorphosis and usually persists throughout the remaining life of the fish (Frost and McCrone 1979). During the day, myctophids stratify in dense aggregations deep in the water column (e.g.,  $\geq 300$  m). These aggregations are sufficiently dense to cause deep sound-scattering layers (e.g., Baird et al. 1975, McCartney 1976). At night, they rise to surface water layers presumably to feed on zooplankton. Bristlemouths exhibit similar diel vertical migrations. Although the eggs and larvae occur in surface waters during both day and night, larger specimens are found between 25 to 325 m at night and from 425 to 725 m during the day (Lancraft et al. 1988). In each case, the migratory life stages are larger than the sizes that would be expected to be subject to entrainment and/or impingement.

During winter we estimate that 303,936 million  $m^3$  of water would pass our hypothetical facility each day. This hypothetical facility represents the total water use by all the projected new facilities which are estimated to withdraw a total of 1.16969 million  $m^3$  of water each day. During winter, the new CWIS facilities would remove 0.00038% of the population passing by the "facility" each day. During summer, the impact would be to remove 0.00052% of the population passing by the facility each day. The projected impacts are small.

## **CONCLUSIONS**

The ichthyoplankton densities in the geographical regions where new CWIS development is projected are low compared to densities seen in shallower depths. This observation coupled with the projected total water use for all new facilities combined suggest a very small impact overall, especially when compared to the impacts projected for coastal LNG facilities proposed for the Gulf. The combined effects from the seven proposed coastal LNG facilities were all deemed to constitute minor adverse impacts. The level of projected impacts from proposed coastal LNG facilities led us to classify the potential impacts from new CWIS facilities as being "very small".

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Table 1. Larval and Egg Densities by Region.

## a) Larval Density

Regions	Count	Minimum	Maximum	Mean	Sum	Standard Deviation	Variance	Standard Error	CI (95%)
C1	352	0.00	245.88	8.78	3091.57	22.96	526.94	1.22	2.40
C2	600	0.04	83.00	4.98	2990.72	7.26	52.69	0.30	0.58
C3	391	0.00	10.14	1.68	656.77	1.44	2.08	0.07	0.14
C4	126	0.06	4.04	0.68	85.40	0.58	0.33	0.05	0.10
C5	778	0.00	2.45	0.42	326.91	0.28	0.08	0.01	0.02
E1	128	0.06	23.81	4.24	542.92	4.57	20.84	0.40	0.79
E2	288	0.02	31.54	3.53	1018.02	3.87	15.01	0.23	0.45
E3	306	0.00	8.23	1.17	356.53	1.13	1.27	0.06	0.13
E4	354	0.00	2.73	0.57	201.79	0.41	0.17	0.02	0.04
E5	352	0.00	3.50	0.39	137.36	0.29	0.09	0.02	0.03
W1	164	0.01	89.43	6.71	1100.28	11.12	123.58	0.87	1.70
W2	413	0.00	538.00	6.58	2718.40	26.89	723.28	1.32	2.59
W3	310	0.08	19.10	2.51	777.07	2.35	5.52	0.13	0.26
W4	51	0.11	2.36	0.52	26.37	0.40	0.16	0.06	0.11
W5	145	0.04	1.62	0.42	60.18	0.25	0.06	0.02	0.04

Table 1.. Continued.

## b) Egg Density

Regions	Count	Minimum	Maximum	Mean	Sum	Standard Deviation	Variance	Standard Error	CI (95%)
C1	352	0.00	168.86	10.2516	3608.5599	22.2440	494.7977	1.19	2.32
C2	600	0.00	207.30	4.1685	2501.0938	10.5791	111.9170	0.43	0.85
C3	391	0.00	5.08	0.6336	247.7475	0.7669	0.5881	0.04	0.08
C4	126	0.00	7.14	0.2375	29.9310	0.7001	0.4901	0.06	0.12
C5	778	0.00	5.10	0.0796	61.9424	0.2150	0.0462	0.01	0.02
E1	128	0.00	74.46	4.0953	524.1963	8.7169	75.9840	0.77	1.51
E2	288	0.02	144.76	2.6500	763.1989	9.1427	83.5883	0.54	1.06
E3	306	0.00	3.64	0.3955	121.0352	0.4033	0.1626	0.02	0.05
E4	354	0.00	13.81	0.2274	80.5140	0.7987	0.6379	0.04	0.08
E5	352	0.00	0.83	0.0537	18.8961	0.0769	0.0059	0.00	0.01
W1	164	0.00	94.82	6.1872	1014.6964	13.7002	187.6958	1.07	2.10
W2	413	0.00	431.00	3.5309	1458.2520	21.5249	463.3195	1.06	2.08
W3	310	0.02	7.35	0.4680	145.0759	0.5992	0.3591	0.03	0.07
W4	51	0.00	0.72	0.1157	5.8989	0.1472	0.0217	0.02	0.04
W5	145	0.00	2.00	0.0789	11.4406	0.1762	0.0311	0.01	0.03



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Table 2. Larval Density by Region and Month.

Region	Month	Larval Density (Mean)	Sample Count	STD	SE	CI (95%)
C1	2	0.12	3.00	0.16	0.09	0.18
C1	3	4.46	36.00	10.57	1.76	3.45
C1	4	1.10	3.00	1.16	0.67	1.31
C1	5	1.45	8.00	1.29	0.46	0.89
C1	6	5.10	36.00	6.60	1.10	2.16
C1	7	23.10	71.00	40.31	4.78	9.38
C1	8	4.59	16.00	4.67	1.17	2.29
C1	9	10.40	82.00	23.08	2.55	4.99
C1	10	3.07	26.00	3.05	0.60	1.17
C1	11	1.19	53.00	1.25	0.17	0.34
C1	12	1.28	18.00	1.03	0.24	0.48
C2	2	0.87	5.00	0.66	0.29	0.58
C2	3	3.53	50.00	3.55	0.50	0.99
C2	4	1.35	9.00	1.64	0.55	1.07
C2	5	5.41	2.00	6.28	4.44	8.70
C2	6	3.40	81.00	2.47	0.27	0.54
C2	7	6.91	108.00	9.93	0.96	1.87
C2	8	3.59	28.00	3.77	0.71	1.40
C2	9	4.94	155.00	4.71	0.38	0.74
C2	10	5.33	44.00	12.76	1.92	3.77
C2	11	5.70	108.00	8.47	0.81	1.60
C2	12	4.88	10.00	6.20	1.96	3.85
C3	1	2.03	18.00	2.21	0.52	1.02
C3	2	1.65	7.00	0.74	0.28	0.55
C3	3	1.77	24.00	1.74	0.36	0.70
C3	4	1.59	17.00	1.69	0.41	0.80
C3	5	1.50	84.00	0.95	0.10	0.20
C3	6	1.24	30.00	1.35	0.25	0.48
C3	7	2.33	19.00	0.98	0.23	0.44
C3	8	1.47	19.00	1.51	0.35	0.68
C3	9	1.70	113.00	1.42	0.13	0.26
C3	10	1.97	10.00	1.74	0.55	1.08
C3	11	1.89	46.00	1.79	0.26	0.52
C3	12	1.01	4.00	0.72	0.36	0.71
C4	1	0.61	3.00	0.03	0.02	0.03
C4	3	0.13	1.00	NA	NA	NA
C4	4	0.50	5.00	0.26	0.12	0.23
C4	5	0.66	40.00	0.40	0.06	0.12
C4	6	0.80	11.00	0.94	0.28	0.55

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Table 2. Continued.

Region	Month	Larval Density (Mean)	Sample Count	STD	SE	CI (95%)
C4	7	1.14	6.00	0.79	0.32	0.63
C4	8	0.45	17.00	0.31	0.07	0.15
C4	9	0.92	29.00	0.74	0.14	0.27
C4	10	0.33	4.00	0.23	0.12	0.23
C4	11	0.39	8.00	0.15	0.05	0.11
C4	12	0.18	2.00	0.02	0.01	0.03
C5	1	0.36	23.00	0.16	0.03	0.07
C5	2	0.62	9.00	0.20	0.07	0.13
C5	3	0.13	2.00	0.09	0.06	0.12
C5	4	0.39	208.00	0.25	0.02	0.03
C5	5	0.45	441.00	0.30	0.01	0.03
C5	6	0.37	56.00	0.28	0.04	0.07
C5	7	0.35	3.00	0.09	0.05	0.10
C5	8	0.21	13.00	0.10	0.03	0.05
C5	9	0.77	5.00	0.40	0.18	0.35
C5	10	0.15	6.00	0.11	0.04	0.09
C5	11	0.27	1.00	NA	NA	NA
C5	12	0.31	11.00	0.16	0.05	0.09
E1	5	10.69	2.00	11.87	8.40	16.45
E1	6	0.80	2.00	0.89	0.63	1.23
E1	7	4.61	2.00	4.33	3.06	6.00
E1	8	8.71	9.00	9.22	3.07	6.03
E1	9	3.89	92.00	3.85	0.40	0.79
E1	10	3.54	21.00	2.70	0.59	1.15
E2	5	4.17	17.00	5.76	1.40	2.74
E2	6	1.78	13.00	1.46	0.40	0.79
E2	7	2.17	8.00	1.76	0.62	1.22
E2	8	3.31	23.00	2.21	0.46	0.91
E2	9	3.89	158.00	4.33	0.34	0.68
E2	10	3.14	69.00	2.93	0.35	0.69
E3	3	1.12	1.00	NA	NA	NA
E3	4	0.70	25.00	0.45	0.09	0.18
E3	5	0.94	77.00	0.92	0.10	0.20
E3	6	0.88	19.00	0.68	0.16	0.31
E3	7	0.42	7.00	0.32	0.12	0.24
E3	8	1.18	15.00	0.98	0.25	0.50
E3	9	1.53	108.00	1.40	0.13	0.26
E3	10	1.12	53.00	1.00	0.14	0.27
E3	12	3.76	1.00	NA	NA	NA

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Table 2. Continued.

Region	Month	Larval Density (Mean)	Sample Count	STD	SE	CI (95%)
E4	3	0.74	6.00	0.98	0.40	0.79
E4	4	0.70	74.00	0.47	0.05	0.11
E4	5	0.55	159.00	0.35	0.03	0.05
E4	6	0.57	30.00	0.41	0.07	0.15
E4	7	0.34	5.00	0.18	0.08	0.16
E4	8	0.39	30.00	0.27	0.05	0.10
E4	9	0.66	28.00	0.45	0.09	0.17
E4	10	0.40	22.00	0.30	0.06	0.12
E5	4	0.38	112.00	0.20	0.02	0.04
E5	5	0.40	207.00	0.33	0.02	0.05
E5	6	0.41	26.00	0.30	0.06	0.11
E5	7	0.10	1.00	NA	NA	NA
E5	8	0.46	2.00	0.33	0.24	0.46
E5	10	0.60	2.00	0.40	0.28	0.55
E5	12	0.19	2.00	0.24	0.17	0.33
W1	6	5.01	20.00	5.83	1.30	2.56
W1	7	6.82	26.00	9.04	1.77	3.48
W1	8	4.74	8.00	4.75	1.68	3.29
W1	9	9.33	72.00	14.88	1.75	3.44
W1	10	2.67	33.00	2.86	0.50	0.98
W1	11	5.03	5.00	6.74	3.01	5.90
W2	2	3.71	1.00	NA	NA	NA
W2	4	1.66	1.00	NA	NA	NA
W2	5	2.38	13.00	2.18	0.60	1.18
W2	6	4.73	81.00	3.79	0.42	0.83
W2	7	4.76	58.00	8.37	1.10	2.15
W2	8	27.40	26.00	104.31	20.46	40.10
W2	9	6.65	128.00	6.60	0.58	1.14
W2	10	4.35	96.00	5.32	0.54	1.06
W2	11	4.62	9.00	2.42	0.81	1.58
W3	1	1.13	10.00	0.28	0.09	0.17
W3	2	1.04	4.00	0.38	0.19	0.37
W3	4	1.20	6.00	0.84	0.34	0.67
W3	5	2.01	35.00	1.74	0.29	0.58
W3	6	2.62	40.00	1.97	0.31	0.61
W3	7	2.65	36.00	2.87	0.48	0.94
W3	8	2.72	17.00	2.11	0.51	1.00
W3	9	2.82	104.00	2.36	0.23	0.45
W3	10	2.57	55.00	2.87	0.39	0.76

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Table 2. Continued.

Region	Month	Larval Density (Mean)	Sample Count	STD	SE	CI (95%)
W3	11	0.99	3.00	0.67	0.39	0.76
W4	1	0.51	3.00	0.19	0.11	0.21
W4	2	0.83	2.00	0.33	0.24	0.46
W4	4	0.37	2.00	0.36	0.25	0.50
W4	5	0.51	17.00	0.37	0.09	0.18
W4	6	0.69	2.00	0.39	0.27	0.53
W4	7	0.27	12.00	0.16	0.05	0.09
W4	8	0.23	2.00	0.05	0.03	0.07
W4	9	0.79	11.00	0.56	0.17	0.33
W5	1	0.29	17.00	0.12	0.03	0.06
W5	2	0.43	5.00	0.14	0.06	0.12
W5	4	0.31	27.00	0.24	0.05	0.09
W5	5	0.47	87.00	0.26	0.03	0.05
W5	6	0.52	3.00	0.23	0.13	0.26
W5	7	0.18	2.00	0.05	0.04	0.07
W5	8	0.54	2.00	0.23	0.16	0.32
W5	9	0.30	2.00	0.02	0.02	0.03

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Table 3. Egg Density by Region and Month.

Region	Month	Egg Density (Mean)	Sample Count	STD	SE	CI (95%)
C1	2	1.89	3	2.54	1.47	2.87
C1	3	20.65	36	30.76	5.13	10.05
C1	4	10.83	3	5.28	3.05	5.98
C1	5	1.88	8	2.97	1.05	2.06
C1	6	16.17	36	32.36	5.39	10.57
C1	7	13.87	71	18.51	2.20	4.31
C1	8	20.99	16	43.23	10.81	21.18
C1	9	7.56	82	17.73	1.96	3.84
C1	10	3.33	26	7.10	1.39	2.73
C1	11	3.49	53	14.20	1.95	3.82
C1	12	1.00	18	2.04	0.48	0.94
C2	2	17.43	5	21.30	9.53	18.67
C2	3	9.91	50	29.23	4.13	8.10
C2	4	5.42	9	6.19	2.06	4.04
C2	5	19.92	2	25.18	17.81	34.90
C2	6	3.48	81	3.59	0.40	0.78
C2	7	5.58	108	8.87	0.85	1.67
C2	8	3.79	28	4.00	0.76	1.48
C2	9	2.89	155	5.67	0.46	0.89
C2	10	2.22	44	5.08	0.77	1.50
C2	11	1.93	108	2.45	0.24	0.46
C2	12	8.54	10	12.34	3.90	7.65
C3	1	0.81	18	0.64	0.15	0.30
C3	2	0.78	7	0.71	0.27	0.52
C3	3	1.24	24	1.48	0.30	0.59
C3	4	0.56	17	0.30	0.07	0.14
C3	5	0.63	84	0.53	0.06	0.11
C3	6	0.62	30	0.75	0.14	0.27
C3	7	0.90	19	1.15	0.26	0.52
C3	8	0.76	19	0.71	0.16	0.32
C3	9	0.47	113	0.57	0.05	0.10
C3	10	0.77	10	1.47	0.47	0.91
C3	11	0.51	46	0.74	0.11	0.21
C3	12	0.25	4	0.20	0.10	0.20
C4	1	0.12	3	0.13	0.08	0.15
C4	3	0.31	1	NA	NA	NA
C4	4	0.19	5	0.18	0.08	0.16
C4	5	0.19	40	0.41	0.06	0.13
C4	6	0.41	11	0.68	0.20	0.40

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Table 3. Continued.

Region	Month	Egg Density (Mean)	Sample Count	STD	SE	CI (95%)
C4	7	0.26	6	0.18	0.07	0.15
C4	8	0.18	17	0.20	0.05	0.10
C4	9	0.36	29	1.31	0.24	0.48
C4	10	0.08	4	0.07	0.04	0.07
C4	11	0.06	8	0.11	0.04	0.08
C4	12	0.22	2	0.16	0.11	0.22
C5	1	0.07	23	0.15	0.03	0.06
C5	2	0.61	9	1.68	0.56	1.10
C5	3	0.21	2	0.01	0.01	0.02
C5	4	0.07	208	0.10	0.01	0.01
C5	5	0.07	441	0.08	0.00	0.01
C5	6	0.06	56	0.05	0.01	0.01
C5	7	0.07	3	0.03	0.02	0.04
C5	8	0.32	13	0.55	0.15	0.30
C5	9	0.04	5	0.03	0.01	0.02
C5	10	0.03	6	0.02	0.01	0.02
C5	11	0.01	1	NA	NA	NA
C5	12	0.10	11	0.24	0.07	0.14
E1	5	11.57	2	12.73	9.00	17.65
E1	6	12.74	2	13.33	9.42	18.47
E1	7	37.73	2	51.95	36.73	71.99
E1	8	8.51	9	8.60	2.87	5.62
E1	9	3.26	92	5.79	0.60	1.18
E1	10	1.14	21	1.03	0.23	0.44
E2	5	4.30	17	6.09	1.48	2.89
E2	6	1.90	13	2.06	0.57	1.12
E2	7	1.87	8	1.71	0.61	1.19
E2	8	4.01	23	7.00	1.46	2.86
E2	9	3.06	158	11.81	0.94	1.84
E2	10	1.09	69	0.86	0.10	0.20
E3	3	1.23	1	NA	NA	NA
E3	4	0.64	25	0.75	0.15	0.30
E3	5	0.40	77	0.33	0.04	0.07
E3	6	0.37	19	0.21	0.05	0.09
E3	7	0.39	7	0.24	0.09	0.18
E3	8	0.61	15	0.53	0.14	0.27
E3	9	0.35	108	0.37	0.04	0.07
E3	10	0.30	53	0.29	0.04	0.08
E3	12	0.18	1	NA	NA	NA

*Cooling Water Intake Structure Biological Baseline Study*

Table 3. Continued.

Region	Month	Egg Density (Mean)	Sample Count	STD	SE	CI (95%)
E4	3	0.30	6	0.35	0.14	0.28
E4	4	0.18	74	0.32	0.04	0.07
E4	5	0.29	159	1.15	0.09	0.18
E4	6	0.20	30	0.30	0.06	0.11
E4	7	0.07	5	0.06	0.03	0.05
E4	8	0.13	30	0.21	0.04	0.07
E4	9	0.23	28	0.35	0.07	0.13
E4	10	0.12	22	0.18	0.04	0.08
E5	4	0.05	112	0.06	0.01	0.01
E5	5	0.06	207	0.09	0.01	0.01
E5	6	0.06	26	0.05	0.01	0.02
E5	7	0.13	1	NA	NA	NA
E5	8	0.02	2	0.00	0.00	0.00
E5	10	0.02	2	0.02	0.01	0.03
E5	12	0.02	2	0.03	0.02	0.04
W1	6	6.84	20	6.34	1.42	2.78
W1	7	11.03	26	20.49	4.02	7.88
W1	8	12.62	8	28.93	10.23	20.05
W1	9	6.20	72	12.65	1.49	2.92
W1	10	0.80	33	1.17	0.20	0.40
W1	11	3.39	5	5.67	2.54	4.97
W2	2	0.60	1	NA	NA	NA
W2	4	0.61	1	NA	NA	NA
W2	5	2.51	13	0.90	0.25	0.49
W2	6	3.36	81	2.44	0.27	0.53
W2	7	3.28	58	5.92	0.78	1.52
W2	8	21.79	26	84.32	16.54	32.41
W2	9	2.28	128	2.51	0.22	0.44
W2	10	0.98	96	1.72	0.18	0.34
W2	11	1.11	9	0.75	0.25	0.49
W3	1	0.22	10	0.11	0.04	0.07
W3	2	0.32	4	0.17	0.09	0.17
W3	4	0.53	6	0.38	0.16	0.31
W3	5	0.66	35	0.54	0.09	0.18
W3	6	0.68	40	0.72	0.11	0.22
W3	7	0.63	36	1.19	0.20	0.39
W3	8	0.54	17	0.44	0.11	0.21
W3	9	0.44	104	0.40	0.04	0.08
W3	10	0.20	55	0.17	0.02	0.05



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Table 3. Continued.

Region	Month	Egg Density (Mean)	Sample Count	STD	SE	CI (95%)
W3	11	0.11	3	0.07	0.04	0.08
W4	1	0.04	3	0.04	0.02	0.04
W4	2	0.06	2	0.04	0.03	0.05
W4	4	0.07	2	0.02	0.01	0.03
W4	5	0.12	17	0.17	0.04	0.08
W4	6	0.10	2	0.11	0.08	0.15
W4	7	0.17	12	0.18	0.05	0.10
W4	8	0.02	2	0.02	0.02	0.03
W4	9	0.12	11	0.13	0.04	0.08
W5	1	0.03	17	0.02	0.01	0.01
W5	2	0.02	5	0.01	0.00	0.01
W5	4	0.08	27	0.06	0.01	0.02
W5	5	0.08	87	0.21	0.02	0.04
W5	6	0.20	3	0.22	0.13	0.25
W5	7	0.38	2	0.21	0.15	0.29
W5	8	0.01	2	0.00	0.00	0.00
W5	9	0.09	2	0.05	0.04	0.07

Table 4. Mean larval density by region based on all samples.

Region	Sum Of Densities	No of Trawls	Average Density
C1	5466.25	1029	5.31219
C2	4730.58	1167	4.05362
C3	861.80	577	1.49359
C4	120.56	193	0.62468
C5	384.15	1036	0.37081
E1	1275.07	229	5.56798
E2	1829.43	471	3.88415
E3	494.00	434	1.13825
E4	248.65	475	0.52348
E5	151.52	419	0.36163
W1	1614.33	253	6.38074
W2	3470.34	596	5.82272
W3	1064.04	430	2.47450
W4	48.63	98	0.49618
W5	91.07	220	0.41394

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Table 5. Most abundant species in zones where new development is expected to occur.

Region	Taxa	Common Name	Density (No.m <sup>3</sup> )	Cumulative Percent of Total Catch	Ecosystem Designation
<b>C4</b> 321 Total Taxa	Engraulidae	Anchovies	0.06012	9.6	Forage
	Myctophidae	Lanternfishes	0.05834	19.0	Forage
	<i>Bregmaceros</i> spp.	Codlets	0.04864	26.8	Forage
	<i>Diaphus</i> spp.	Lanternfishes	0.04681	34.2	Forage
	<i>Gonostomatidae</i>	Bristlemouths	0.04501	41.4	Forage
	Gobiidae	Gobies	0.03966	47.8	
	Unidentified Fish		0.03274	53.0	
	Synodontidae	Lizardfishes	0.01990	56.2	Forage
	<i>Hygophum</i> spp.	Lanternfishes	0.01511	58.6	Forage
	<i>Maurollicus muelleri</i>	Mueller's bristlemouth	0.01506	61.1	Forage
	<b>Total Mean Density All taxa</b>		<b>0.62468</b>		

Region	Taxa	Common Name	Density (No.m <sup>3</sup> )	Cumulative Percent of Total Catch	Ecosystem Designation
<b>C5</b> 457 Total Taxa	Myctophidae	Lanternfishes	0.05194	14.0	Forage
	<i>Diaphus</i> spp.	Lanternfishes	0.04056	24.9	Forage
	<i>Gonostomatidae</i>	Bristlemouths	0.02592	31.9	Forage
	<i>Hygophum</i> spp.	Lanternfishes	0.02566	38.9	Forage
	Unidentified Fish		0.02382	45.3	
	<i>Cyclothone</i> spp.	Bristlemouths	0.01906	50.4	Forage
	<i>Myctophum</i> spp.	Lanternfishes	0.01606	54.8	Forage
	<i>Bregmaceros</i> spp.	Codlets	0.01248	58.1	Forage
	<i>Benthosema</i> spp.	Lanternfishes	0.01189	61.3	Forage
	<i>Notolychnus valdiviae</i>	Lanternfish	0.00778	63.4	Forage
	<b>Total Density All taxa</b>		<b>0.37075</b>		

Region	Taxa	Common Name	Density (No.m <sup>3</sup> )	Cumulative Percent of Total Catch	Ecosystem Designation
<b>W4</b> 244 Total Taxa	Myctophidae	Lanternfishes	0.07271	14.7	Forage
	<i>Bregmaceros</i> spp.	Codlets	0.04734	24.2	Forage
	Gobiidae	Gobies	0.03816	31.9	
	<i>Diaphus</i> spp.	Lanternfishes	0.03441	38.8	Forage
	<i>Hygophum</i> spp.	Lanternfishes	0.02711	44.3	Forage
	<i>Gonostomatidae</i>	Bristlemouths	0.02587	49.5	Forage
	Unidentified Fish		0.01951	53.4	
	<i>Cyclothone</i> spp.	Bristlemouths	0.01935	57.3	Forage
	Engraulidae	Anchovies	0.01616	60.6	Forage
	Scombridae	Mackerels	0.01013	62.6	
	<b>Total Density All taxa</b>		<b>0.49618</b>		

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Table 5. Continued.

Region	Taxa	Common Name	Density (No.m <sup>3</sup> )	Cumulative Percent of Total Catch	Ecosystem Designation
<b>W5</b> 284 Total Taxa	Myctophidae	Lanternfishes	0.05889	14.2	Forage
	<i>Gonostomatidae</i>	Bristlemouths	0.03183	21.9	Forage
	<i>Bregmaceros</i> spp.	Codlets	0.02976	29.1	Forage
	<i>Cyclothone</i> spp.	Bristlemouths	0.02631	35.5	Forage
	<i>Diaphus</i> spp.	Lanternfishes	0.02392	41.2	Forage
	Unidentified Fish		0.02049	46.2	
	Gobiidae	Gobies	0.01978	51.0	
	<i>Hygophum</i> spp.	Lanternfishes	0.01523	54.6	Forage
	<i>Benthoosema</i> spp.	Lanternfishes	0.01279	57.7	Forage
	<i>Notolychnus</i> <i>valdiviae</i>	Lanternfish	0.01124	60.5	Forage
	<b>Total Density All taxa</b>		<b>0.41393</b>		

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
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